

LBNL BaBar Group

R. Cahn

Oct. 24, 2002



LBL BaBar Group Members

Senior Staff

G. Abrams	D. Brown	R. Cahn	R. Jacobsen
R. Kadel	Y. Kolomensky	M. Pripstein (on leave at DOE)	
N. Roe (also SNAP)	M. Ronan (also NLC)		

Retirees

R. Kerth	J. Kadyk	G. Lynch	W. Wenzel
----------	----------	----------	-----------

Postdocs

A. Borgland	E. Charles	A. Gritsan	L. Mir
V. Shelkov			

Students

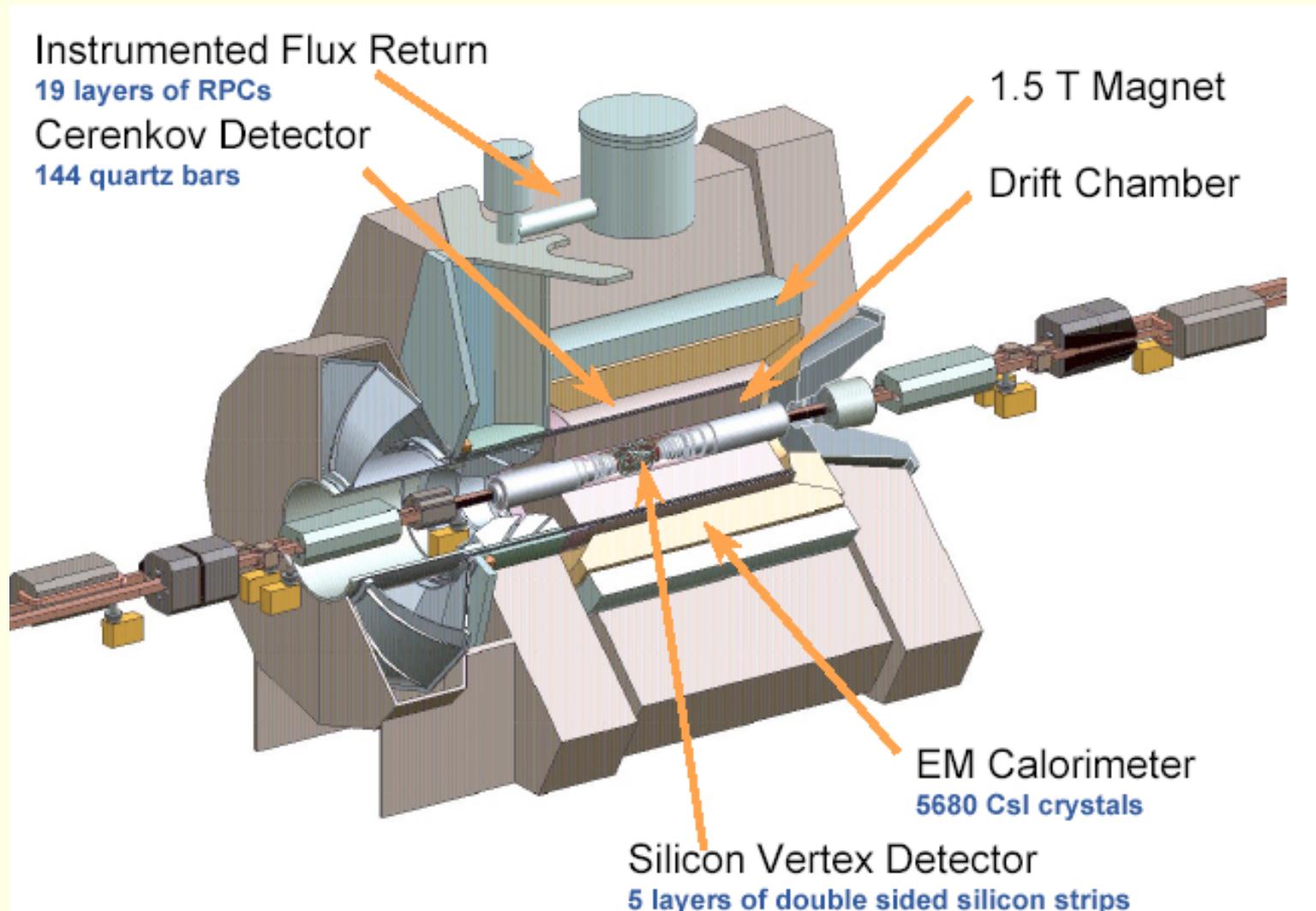
A. Breon	M. Gill	Y. Groysman	G. Kukartsev
C. LeClerc (Ph.D)	A. Mintz	T. Orimoto	A. Telnov

Visitors

J. Button-Schafer	K. Tackmann
-------------------	-------------



BaBar Detector





LBL Leadership Roles in BaBar

- Anders Borgland Trigger commissioner
- David Brown: Computing Model Working Group
- Bob Cahn: Long-range Task Force, Publications Board
- Andrei Gritsan Tracking co-ordinator
- Yury Kolomensky: CMWG Co-chair, B-reco AWG co-convenor
- Pier Oddone: Executive Board
- Natalie Roe: Exclusive Semileptonic Decays AWG co-convenor, Long-range Task Force, IFR Upgrade Review Committee, Membership Committee (chair)
- Vasia Shelkov DIRC Online Coordinator

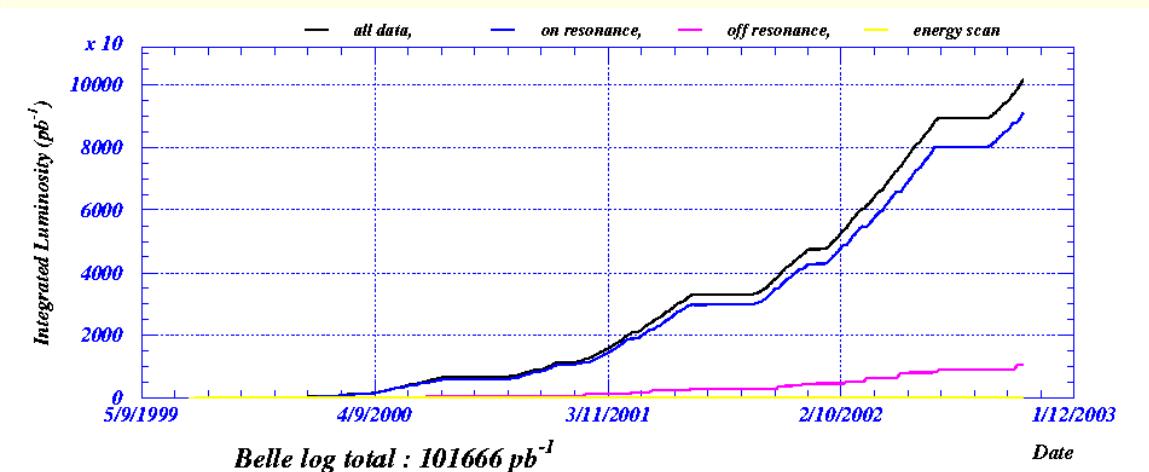
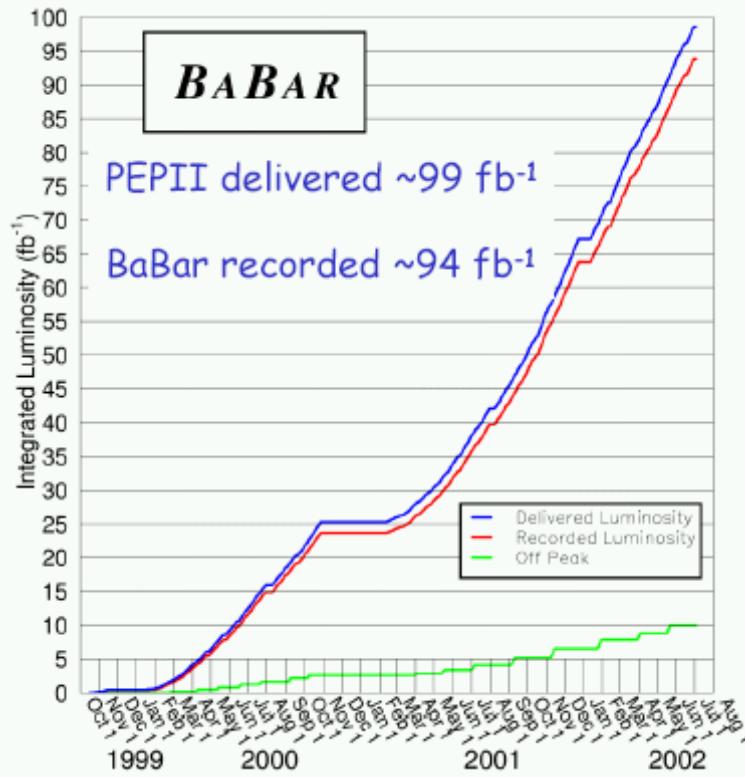


LBL's BaBar Legacy

- Proposal of asymmetric collider (Oddone)
- SVT; co-system manager (Roe), electronics lead (I. Kipnis), mechanical lead (Kerth, F. Goozen)
- Leadership of DIRC barrel mechanical (Kadel, Pripstein)
- Development of drift chamber readout chip (Levi)
- Trigger co-ordinator, L1 charged track trigger (Kral, Levi),
- Leadership of reconstruction software (R. Jacobsen)
- Online co-ordinator (G. Abrams, C. Day)
- Online calibration co-ordinator & DIRC online co-ordinator (D. Brown)



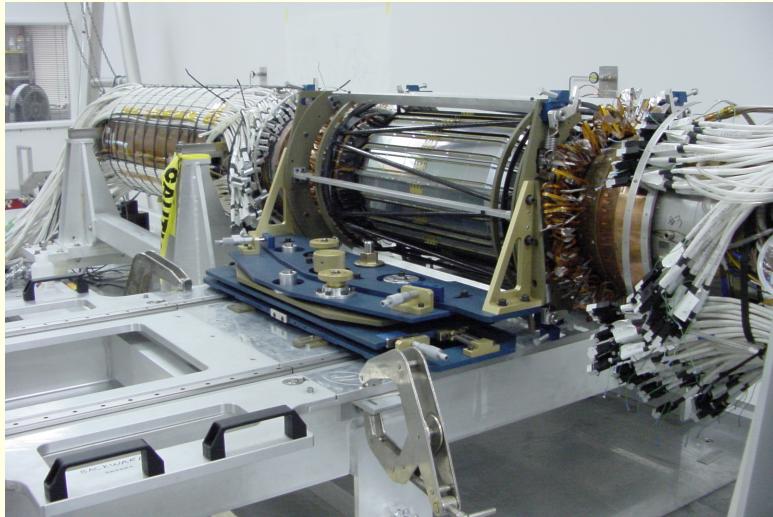
PEP-II and KEK-B Performance



If PEP-II and KEK-B continue to have comparable luminosities, the advantage will go to the collaboration that better maintains its detector and is more innovative in its analysis.



SVT Summer Refurbishing





SVT Status

- Radiation exposure 10 times expected
- SVT performance not degraded
- Major module replacement put off to summer 2005
- Only nine read-out sections of 208 were not working
- Summer refurbishing fixed six
- Fewer than 2% of SVT channels are dead



PEP-II and BaBar Schedule

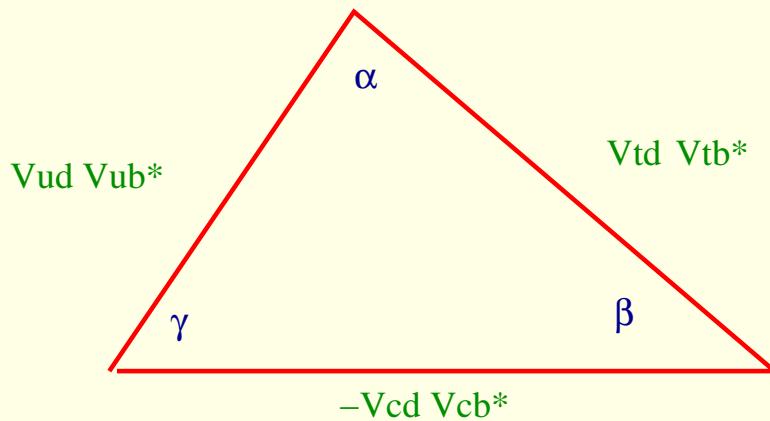
- 100 fb^{-1} delivered so far
- PEP-II turns on November 15, 2002
- Two month shutdown summer 2003
- 2003 goals: 50 fb^{-1} , $\mathcal{L} = 1 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$



BaBar Physics

- Challenge Standard Model description of CP violation
- CKM matrix provides weak phases

$$\begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix} = \begin{bmatrix} 1 - \lambda^2/2 & \lambda & \lambda^3 A(\rho - i\eta) \\ -\lambda & 1 - \lambda^2 & \lambda^2 A \\ \lambda^3 A(1 - \rho - i\eta) & -\lambda^2 & 1 \end{bmatrix} \quad (1)$$



- Measure $\sin 2\beta$ in $B \rightarrow J/\psi K_S$, etc.
- Measure $\sin 2\alpha$ in $B \rightarrow \pi\pi, \rho\pi$ etc.
- Measure γ in $B \rightarrow D\bar{K}$, etc.
- Measure V_{ub}, V_{cb}



Mixing



$B^0 - \bar{B}^0$ Oscillations: $|B_{phys}^0(t)\rangle = \cos \frac{1}{2}\Delta M t |B^0\rangle + i \frac{q}{p} \sin \frac{1}{2}\Delta M t |\bar{B}^0\rangle$

Unmixed: Probability that B^0 remains B^0 :

$$|\langle B^0 | B_{phys}^0(t) \rangle|^2 = |\cos \frac{1}{2}\Delta M t|^2 = \frac{1}{2}(1 + \cos \Delta M t)$$

Mixed: Probability that B^0 becomes \bar{B}^0 :

$$|\langle \bar{B}^0 | B_{phys}^0(t) \rangle|^2 = |\sin \frac{1}{2}\Delta M t|^2 = \frac{1}{2}(1 - \cos \Delta M t)$$

Reconstruct one B , “tag” the other, i.e. determine if it was B^0 or \bar{B}^0

Unmixed: $\frac{1}{2}[1 + D \cos \Delta M t]$

Dilution $D = 1 - 2 \times (\text{wrong} - \text{tag probability})$

Mixed: $\frac{1}{2}[1 - D \cos \Delta M t]$



CP Violation

Direct CP violation: $\Gamma(B^+ \rightarrow XY) \neq \Gamma(B^- \rightarrow \overline{XY})$

Indirect: Final state $f = \text{CP eigenstate (eigenvalue } \eta)$

$$\begin{aligned}\mathcal{A}(t) &= \cos \frac{1}{2} \Delta M t \langle f | \mathcal{H} | B^0 \rangle + i \frac{q}{p} \sin \frac{1}{2} \Delta M t \langle f | \mathcal{H} | \overline{B}^0 \rangle \\ &\propto \cos \frac{1}{2} \Delta M t + i \lambda \sin \frac{1}{2} \Delta M t\end{aligned}\tag{2}$$

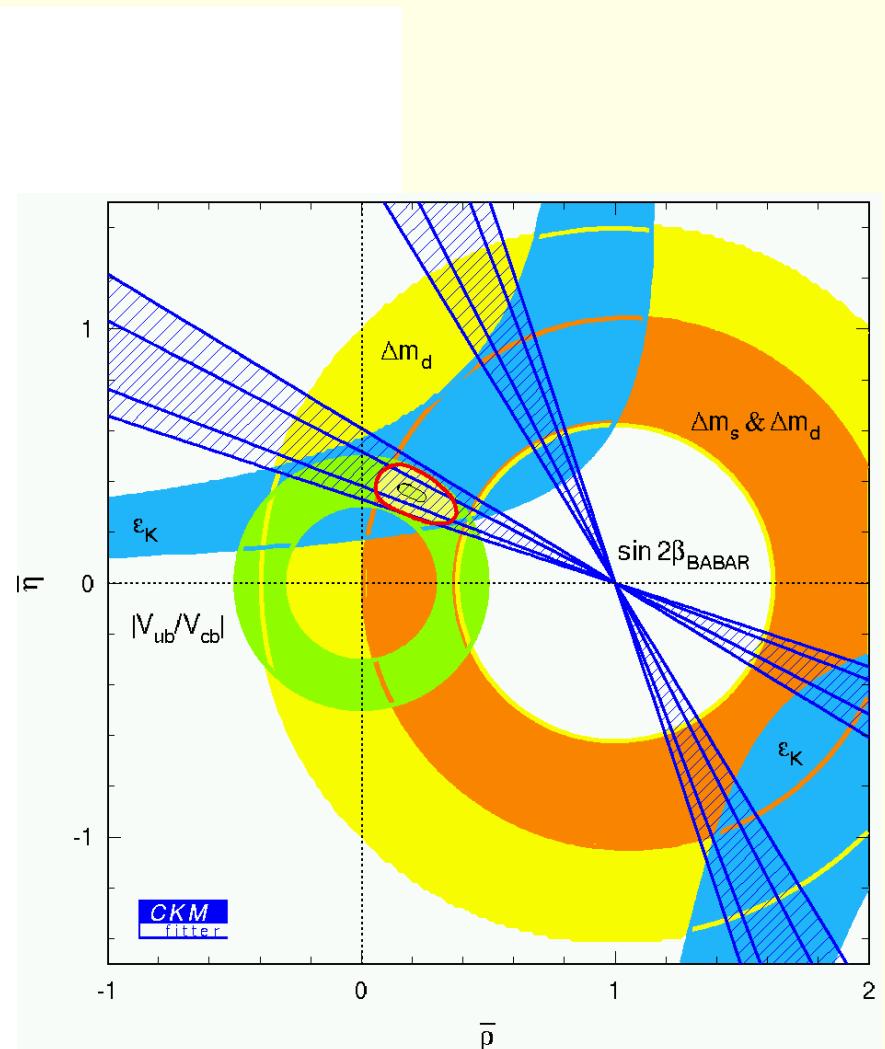
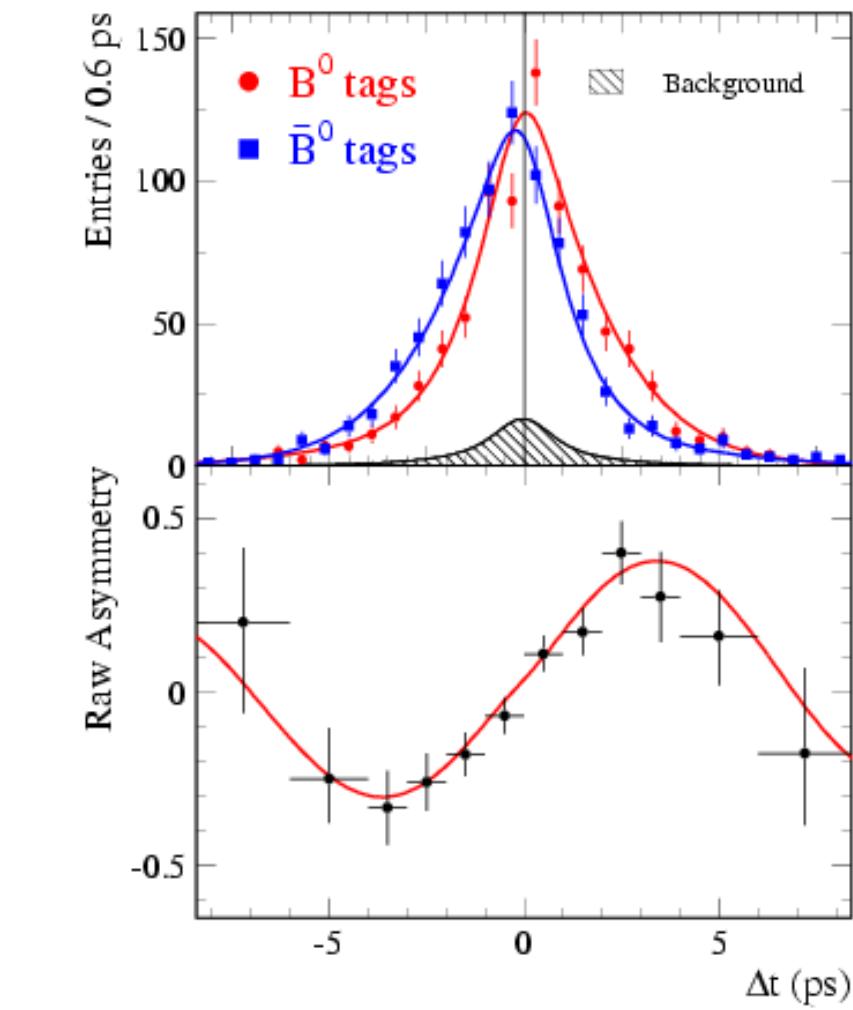
General expression for time-dependent CP violation:

$$|\mathcal{A}(t)|^2 \propto \frac{1}{2}[1 + |\lambda|^2] \pm \frac{1}{2}[1 - |\lambda|^2] \cos \Delta M t \mp \Im \lambda \sin \Delta M t\tag{3}$$

E.g. $\lambda = -e^{-2i\beta} :$ $|\mathcal{A}(t)|^2 \propto 1 - \sin 2\beta \sin \Delta M t$



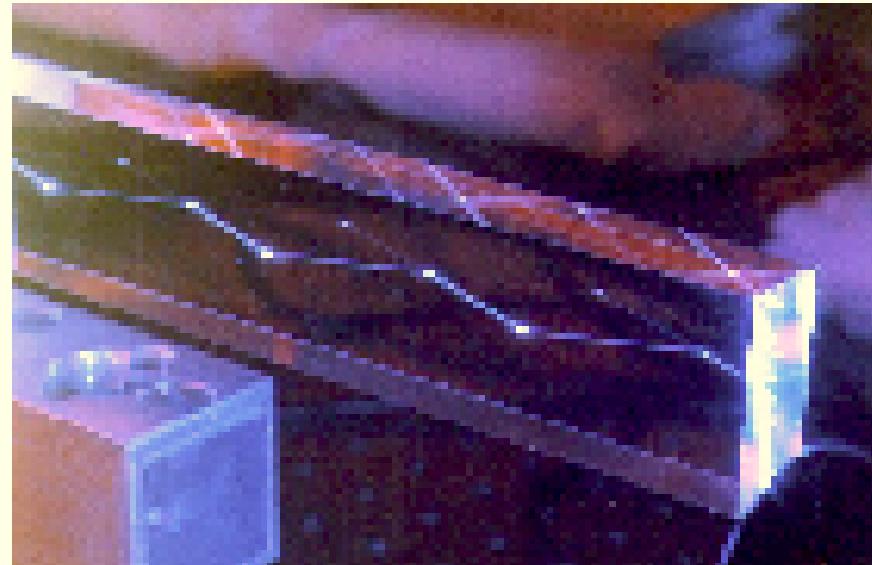
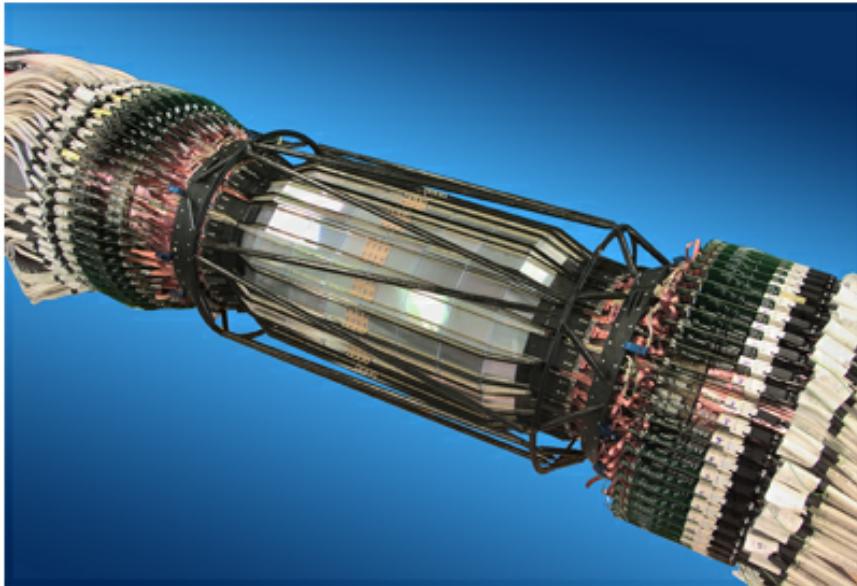
Flagship Result: $\sin 2\beta$



$$\sin 2\beta = 0.741 \pm 0.067(\text{stat}) \pm 0.033(\text{syst})$$



Particular LBL Impact on $\sin 2\beta$



SVT [Roe, Kerth, Goozen]:
vertexing, Δt measurement

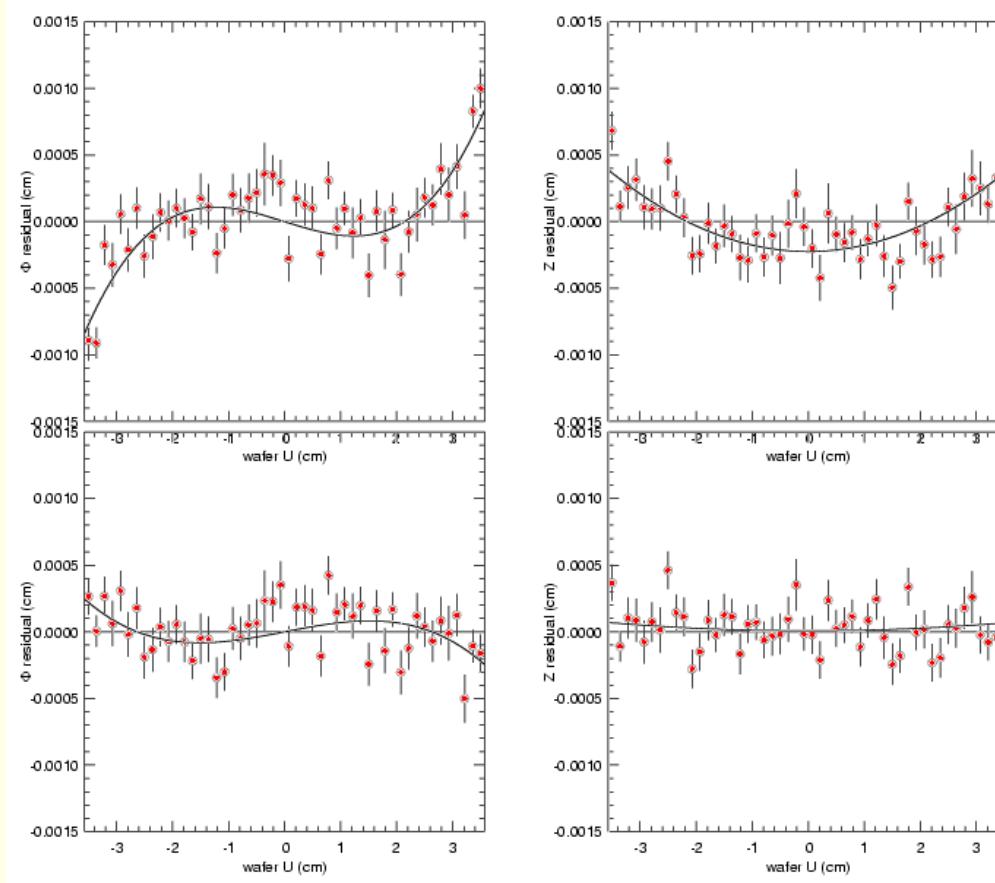
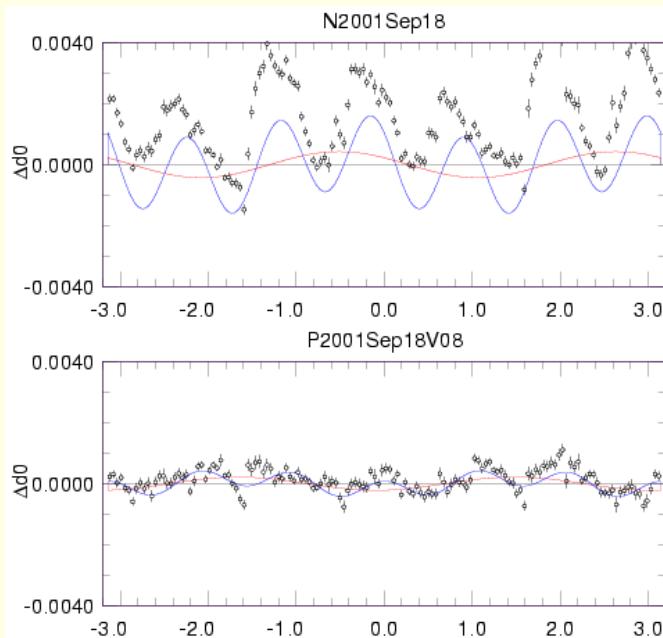
Reconstruction Software: [Jacobsen]

DIRC [Kadel, Brown, Pripstein]:
 K id

Fitting, Tagging, Mixing: [Cahn,
LeClerc, Roe]



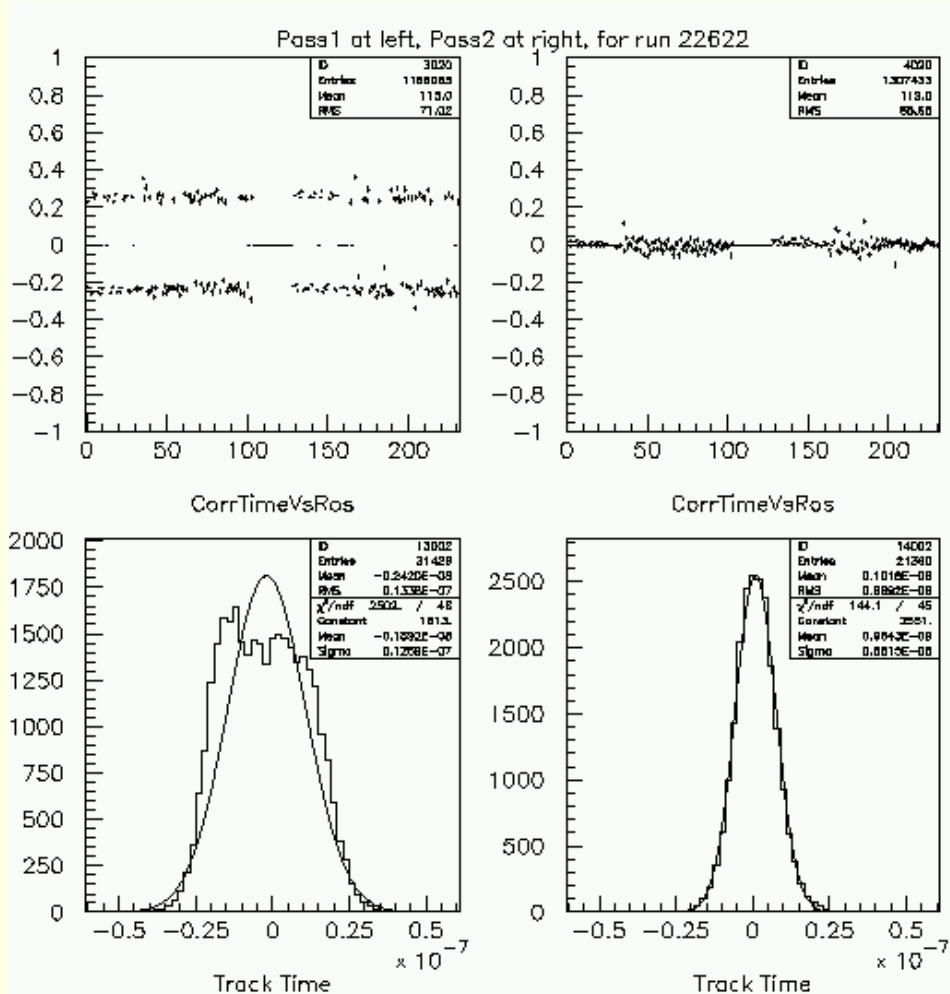
SVT Local Alignment [Brown, Gritsan, Lynch]



LBNL-Maryland team addresses major systematic of $\sin 2\beta$. Use mini-dst, tracks from cosmics, μ pair, other tracks. Mini makes possible enormous time reduction for alignment. Added individual wafer curvature.



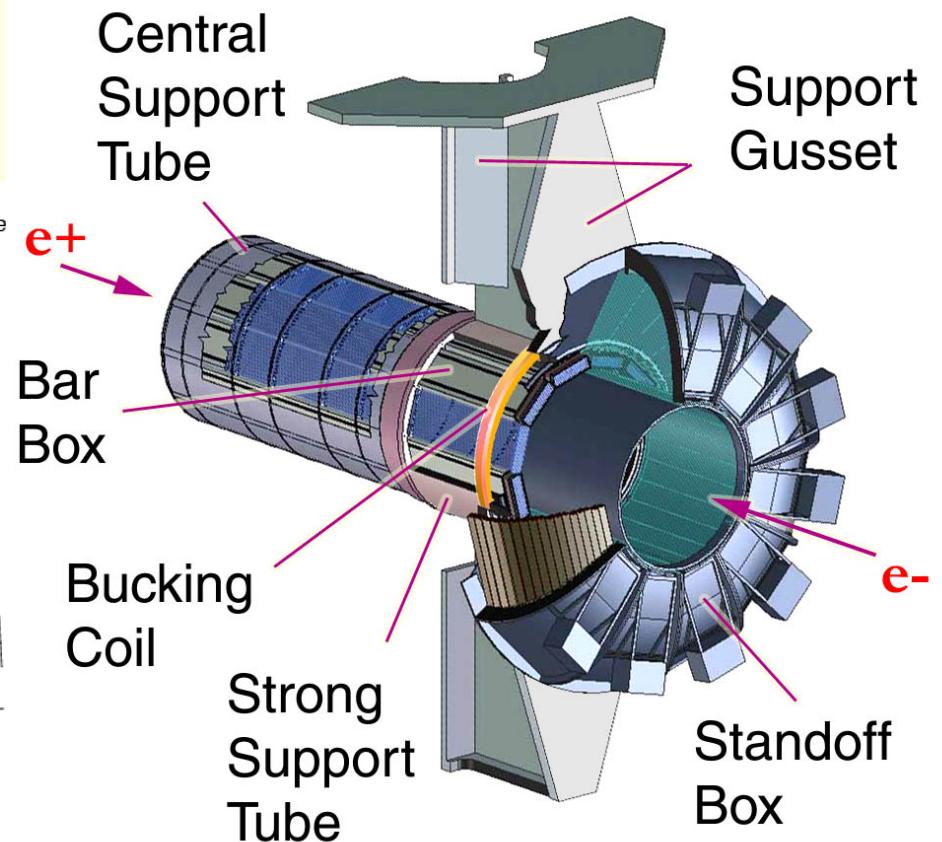
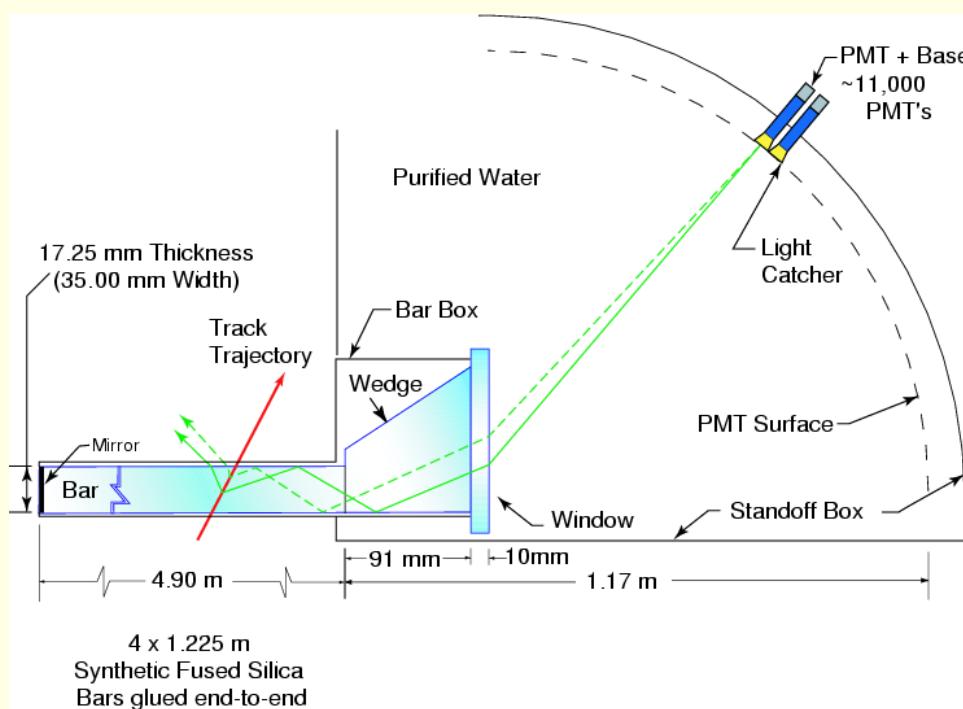
LBL Work on SVT Timing [Lynch]



- AToM chip can be in two phases wrt to DAQ timing
- This gets reset about once per shift
- Wrong timing leads to increased background
- Now can be corrected with two passes



LBL Work on DIRC and Particle ID

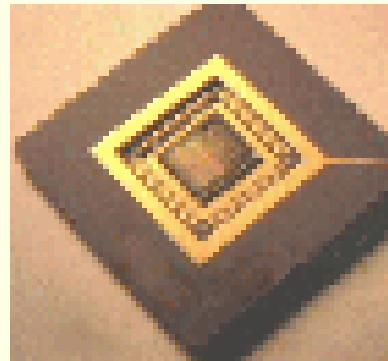
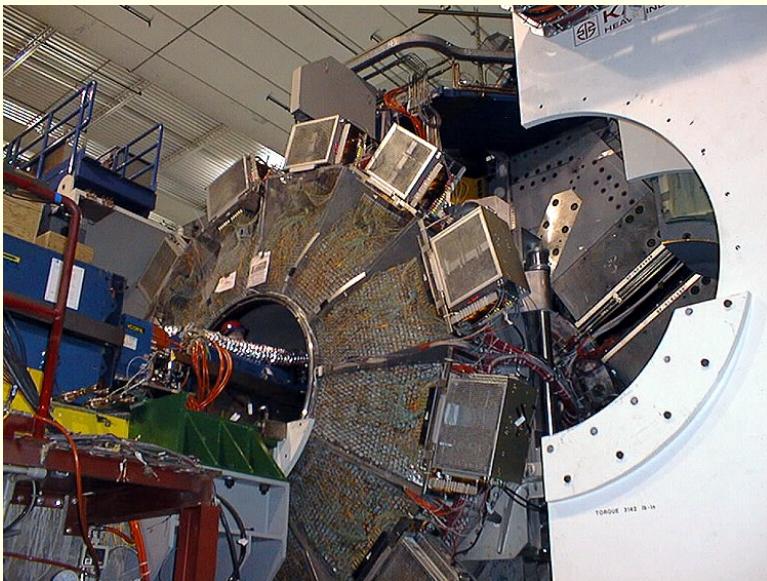




DIRC TDC2 Summer Upgrade

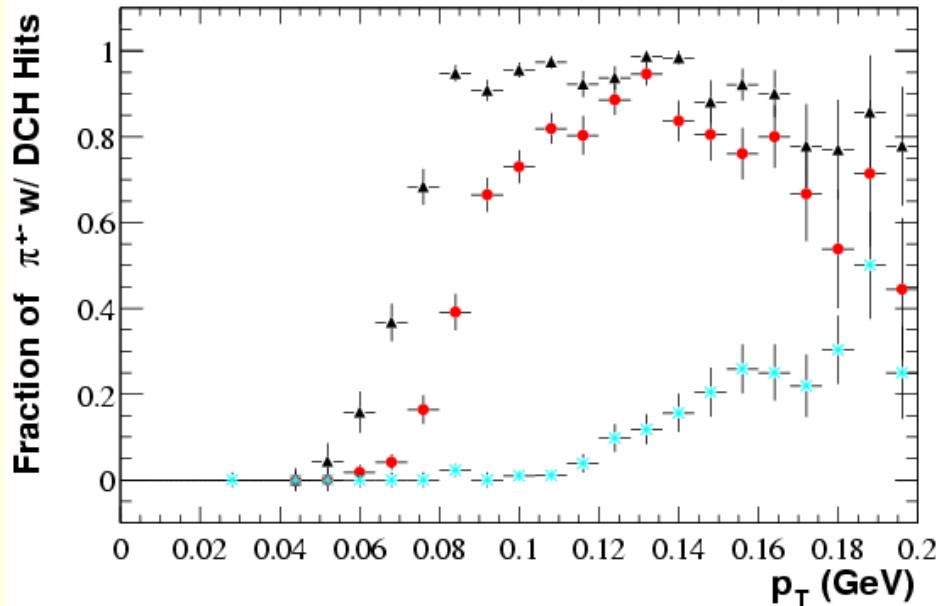


V. Shelkov: Online co-ordinator, testing of new TDC designed by French team.

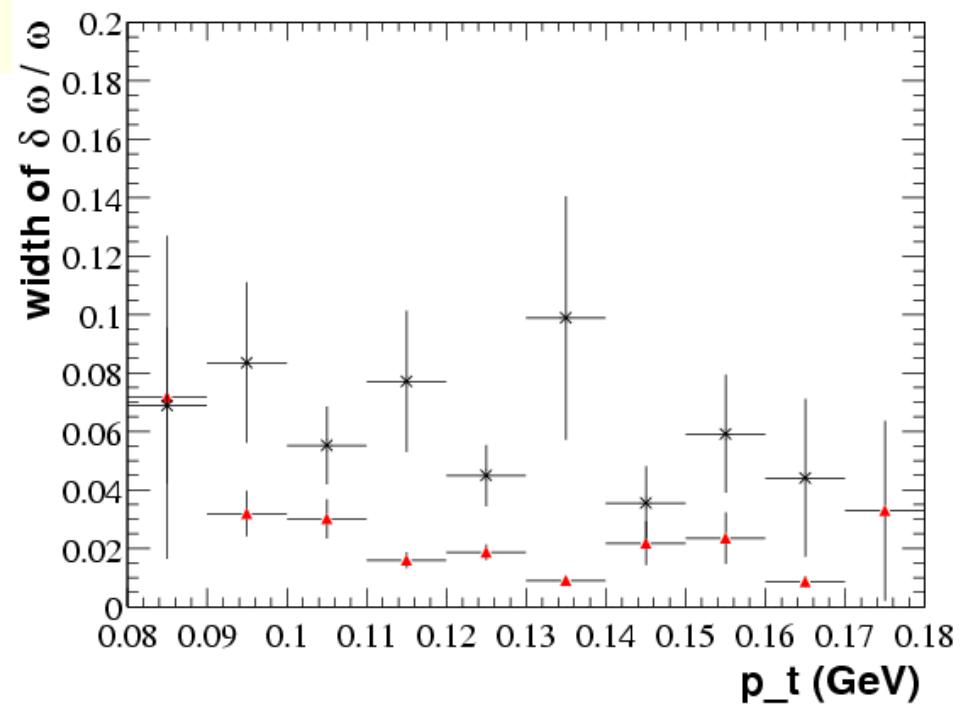




Recover Drift Chamber Hits [Charles]



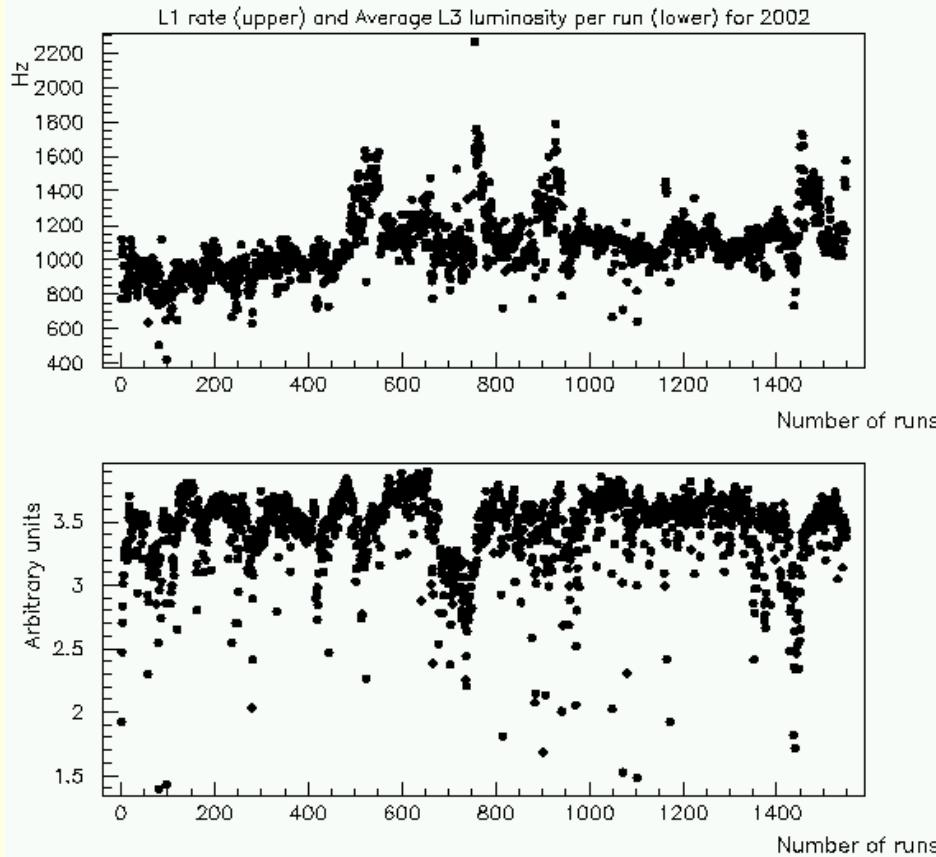
Old algorithm (turquoise) lost DCH hits from low p_\perp tracks. New algorithm (red) approaches MC truth (black). For events with no DCH track found, shows fraction of DCH hits found.



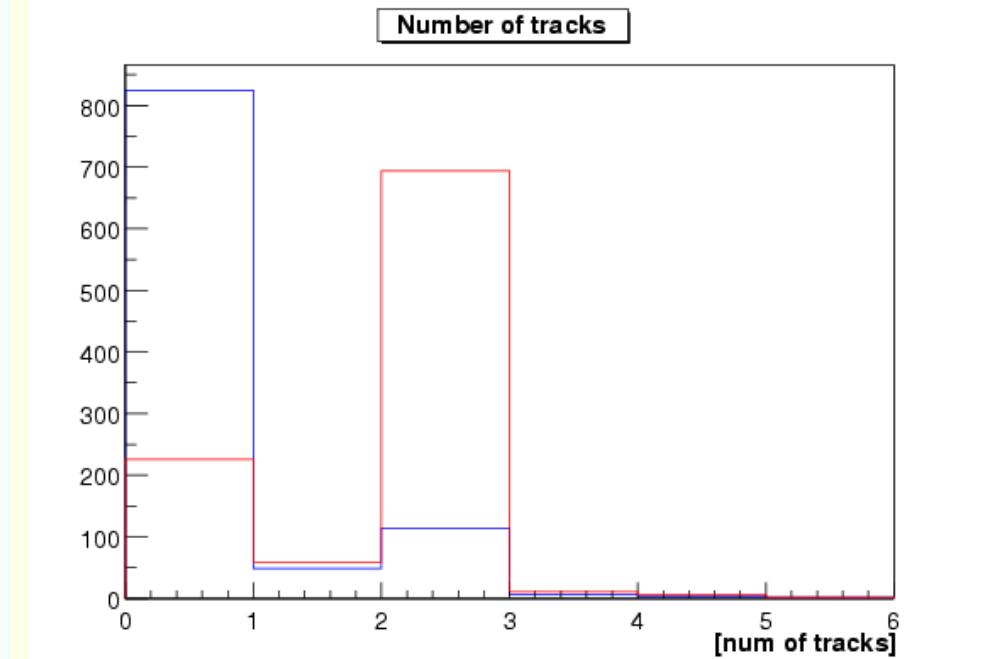
Result is reduced error in curvature (ω).



LBL Work on the Trigger [Borgland]



Upper: L1 trigger rate run by run.
Good running interrupted by bad
conditions. Lower: luminosity, run-
by-run.



Machine background description in
MC improved. With two background
tracks, now reconstruct them. Didn't
before.

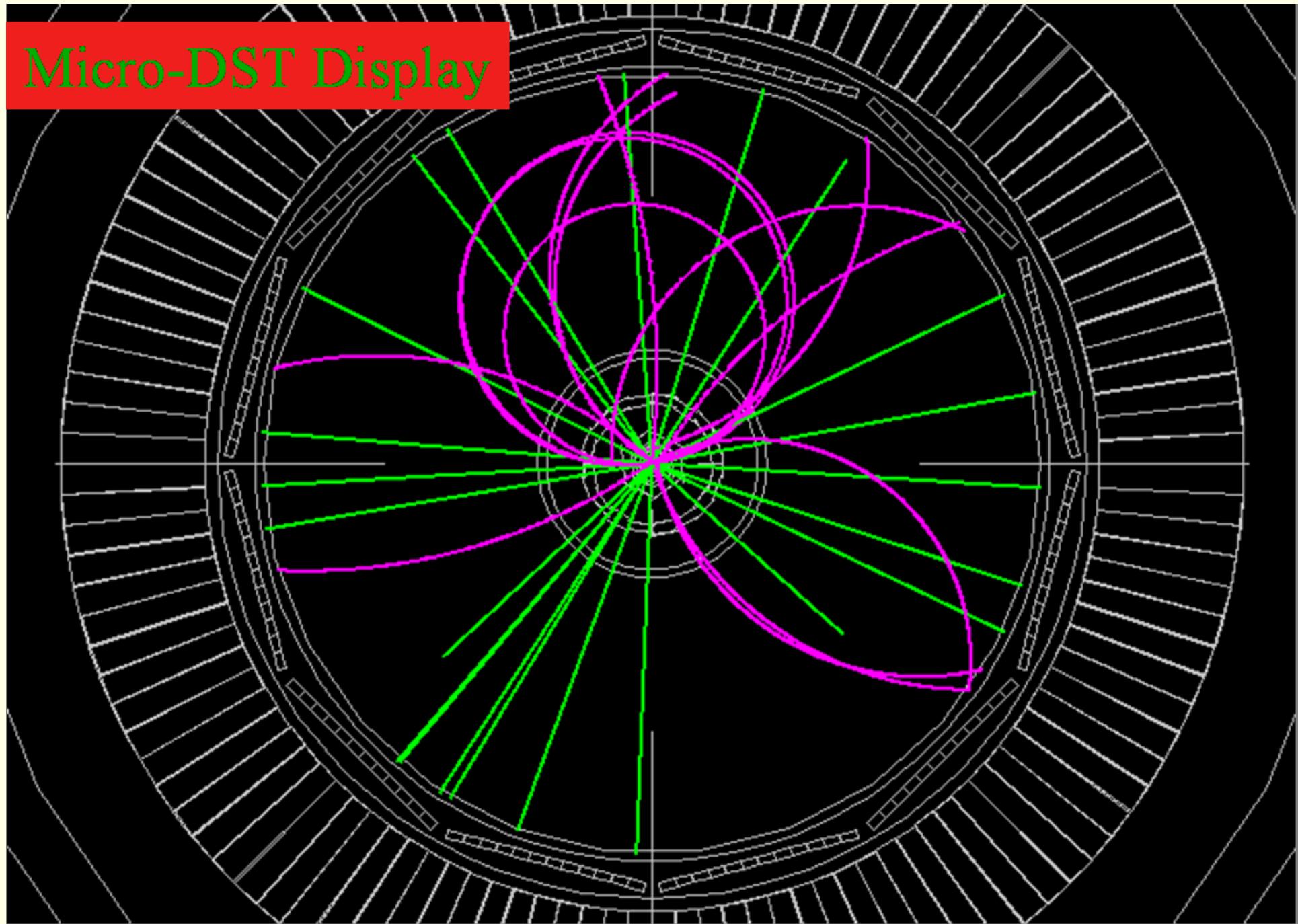


LBL Work on Software[Brown]

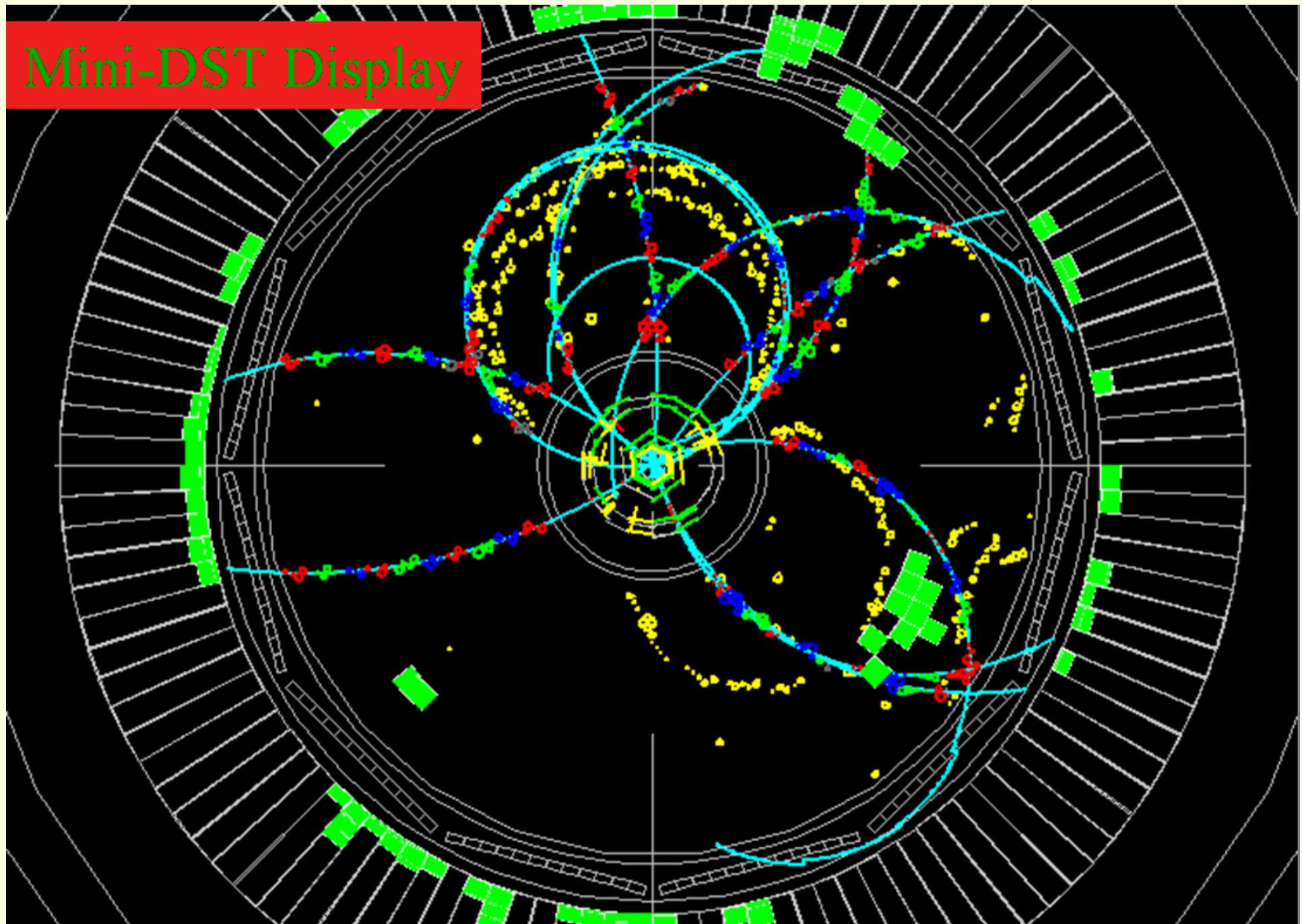


- D. Brown heads team
 - Physics Division: Brown, Jacobsen, Kolomensky
 - NERSC: I. Gaponenko, A. Mokhtarani, S. Patton (now Ice³)
 - MOA with SLAC calls for third computing professional
- Mini-DST replaces twenty-times larger versions of the reconstruction output
- Mini provides access to detailed detector data. Micro did not.
- Mini is the wave of the future
 - Lauded by April 2002 Computing Review
 - To be endorsed by Computing Model Working Group 2
 - Will be central to future physics analyses
- Major contribution by LBNL with broad impact

Micro-DST Display

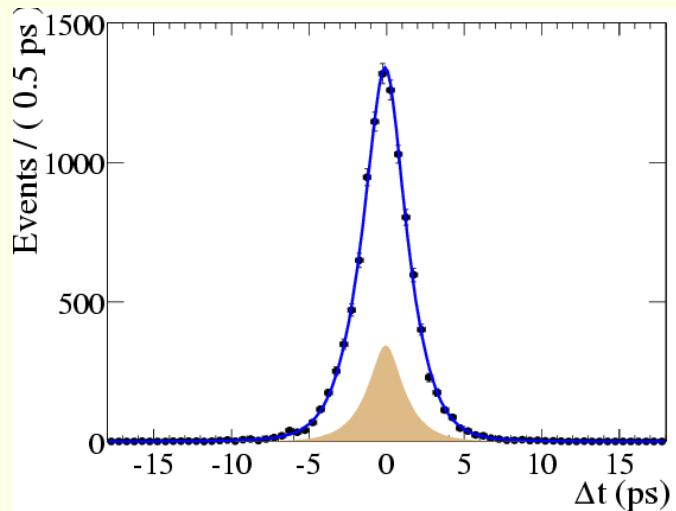


Mini-DST Display

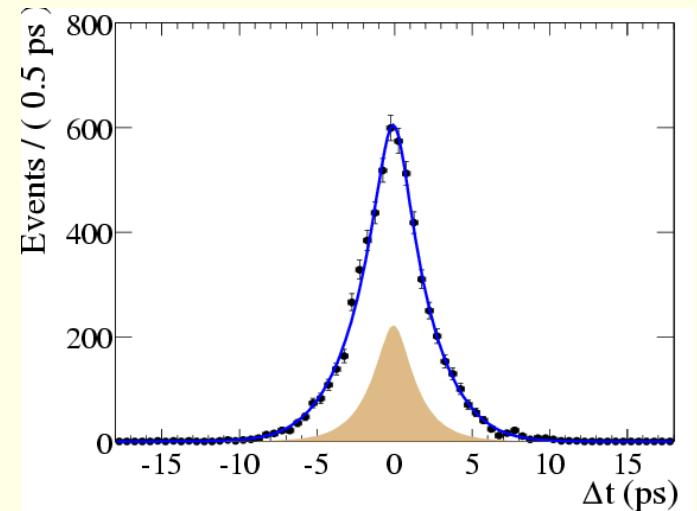




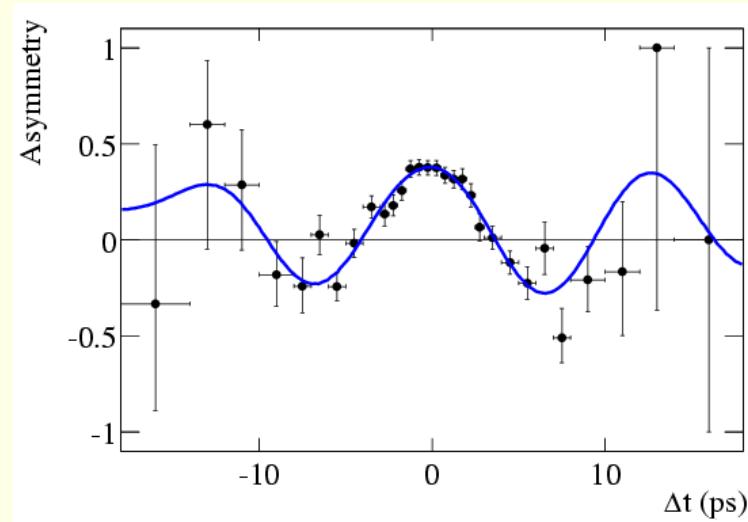
Δm and τ_{B^0} from $B \rightarrow D^* \ell \nu$ [LeClerc]



Unmixed



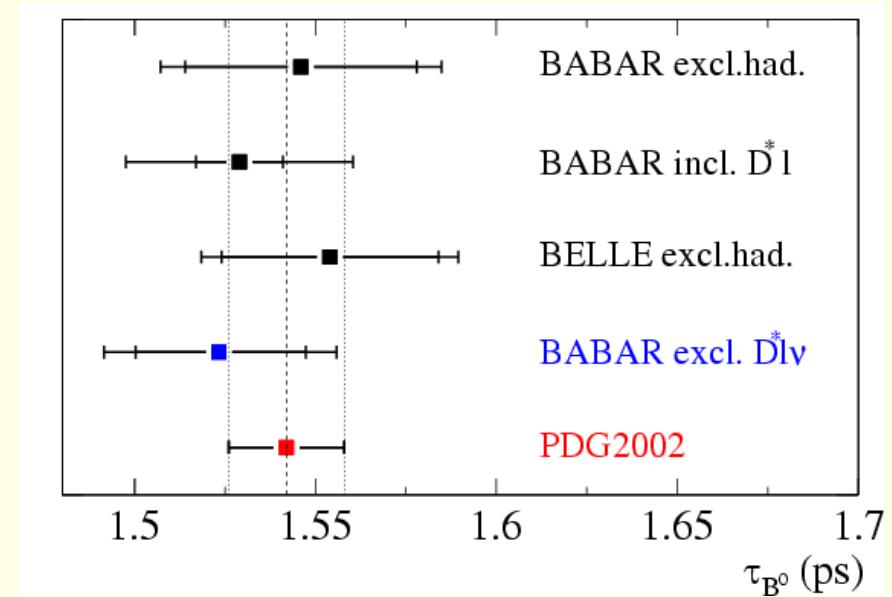
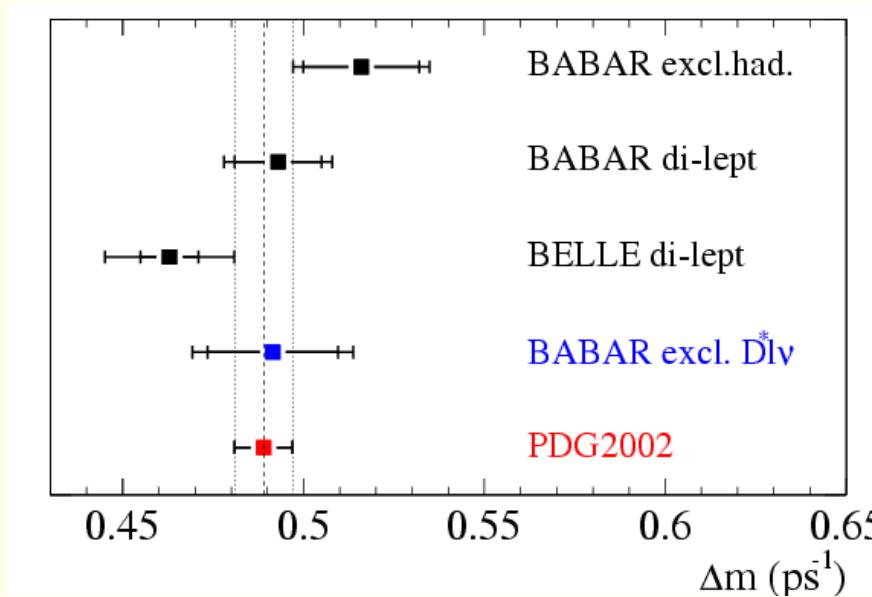
Mixed



- 20.6 fb^{-1} on resonance data
- $\Delta m_d = 0.492 \pm 0.018 \pm 0.013 \text{ ps}^{-1}$
- $\tau_{B^0} = 1.523^{+0.024}_{-0.023} \text{ ps}$



Compare Δm and τ_{B^0} values





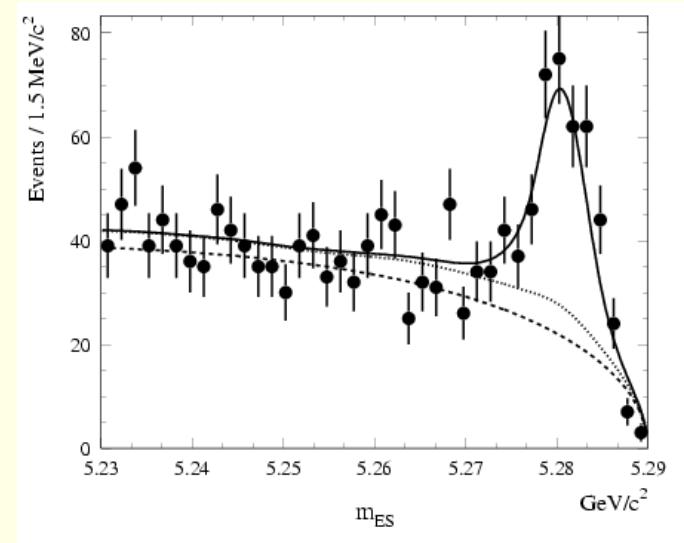
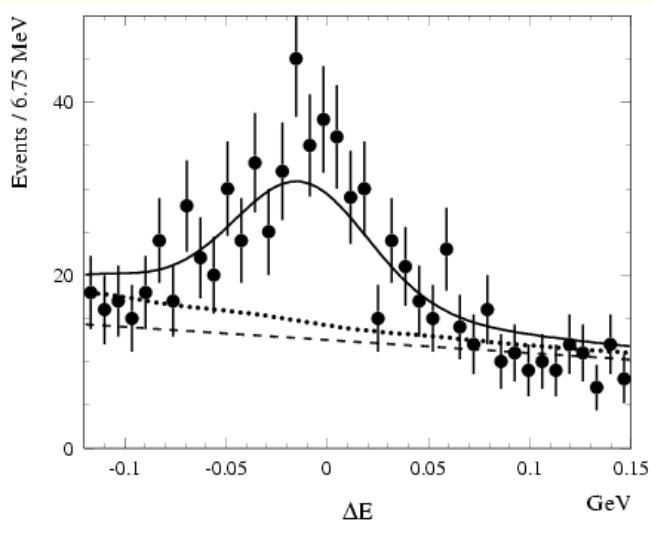
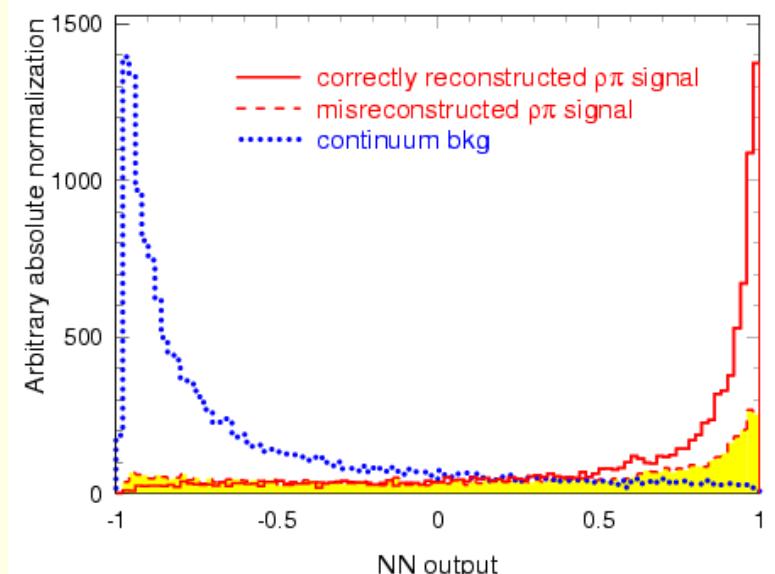
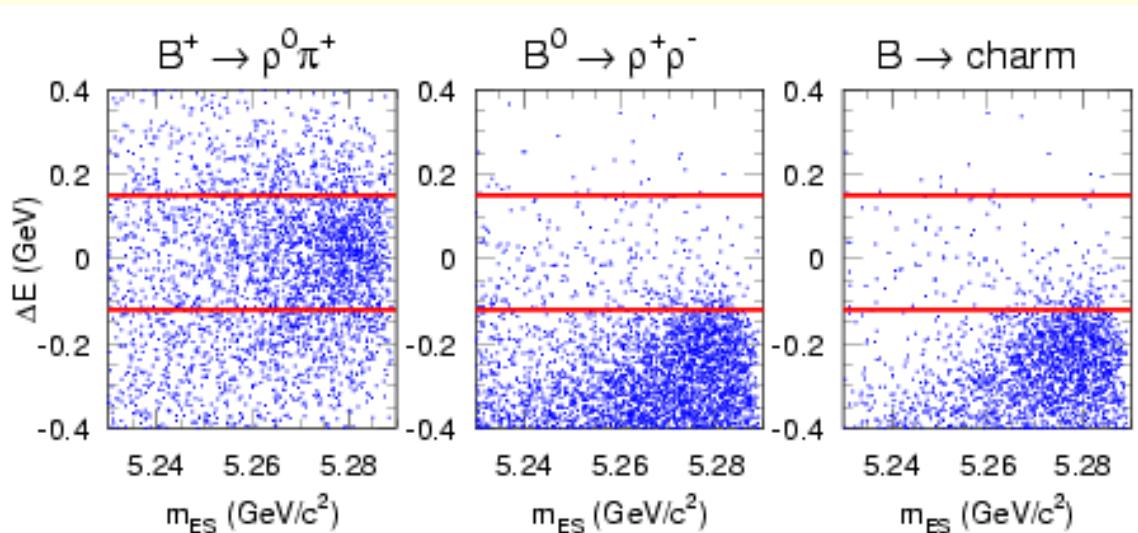
Towards $\alpha : B \rightarrow \rho\pi$ [Shelkov]



- Alternative to $\pi\pi$ for measuring α
- Bigger signal, bigger background
- Ultimate aim: time-dependent Dalitz plot
- Current aim: measurement of CP violation
- Treat ρ as final particle, ignore interference region
- $\rho^\pm\pi^\mp$ only
- Separate background using mass, energy, event shape

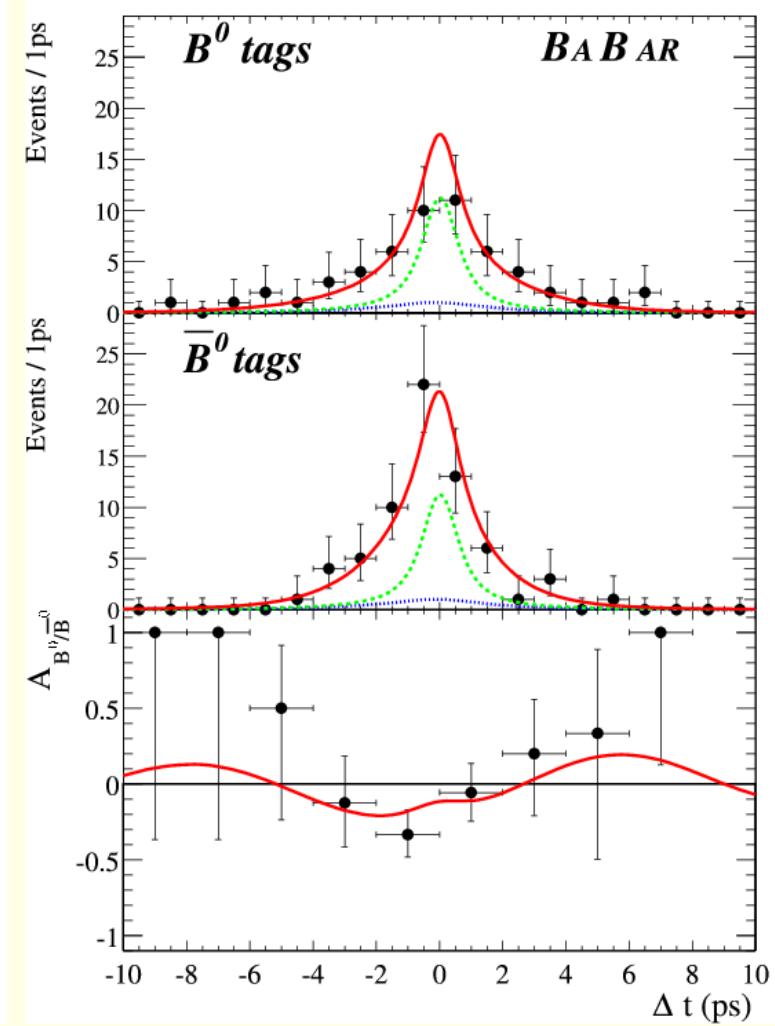
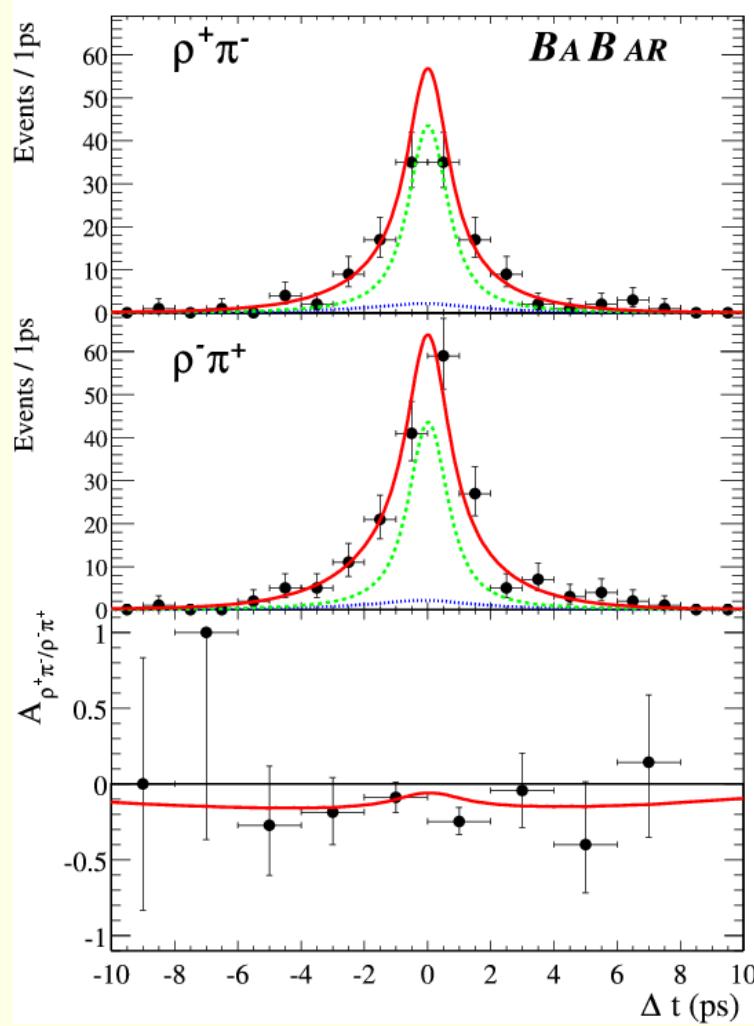


Isolating the $\rho\pi$ signal





$B \rightarrow \rho\pi$ Results





Time-dependent Analysis

$$f_{B^0 \text{tag}}^{\rho^\pm h^\mp} \propto (1 \pm A_{CP}^{\rho h}) \left[1 + \left((S_{\rho h} \pm \Delta S_{\rho h}) \sin(\Delta m_d \Delta t) \right. \right.$$

$$\left. \left. - (C_{\rho h} \pm \Delta C_{\rho h}) \cos(\Delta m_d \Delta t) \right) \right],$$

$$f_{\overline{B}^0 \text{tag}}^{\rho^\pm h^\mp} \propto (1 \pm A_{CP}^{\rho h}) \left[1 - \left((S_{\rho h} \pm \Delta S_{\rho h}) \sin(\Delta m_d \Delta t) \right. \right.$$

$$\left. \left. - (C_{\rho h} \pm \Delta C_{\rho h}) \cos(\Delta m_d \Delta t) \right) \right].$$

$$C_{\rho K} = 0, \Delta C_{\rho K} = -1, S_{\rho K} = 0, \Delta S_{\rho K} = 0$$

CP violating: $A_{CP}^{\rho K}, A_{CP}^{\rho \pi}, S_{\rho \pi}, C_{\rho \pi}$



CP Results in $B \rightarrow \rho^\pm \pi^\mp$

413^{+34}_{-33} (stat) $\rho\pi$ and 147^{+22}_{-21} (stat) ρK events

$$A_{CP}^{\rho K} = 0.19 \pm 0.14 \text{ (stat)}, \quad A_{CP}^{\rho\pi} = -0.22 \pm 0.08 \text{ (stat)},$$

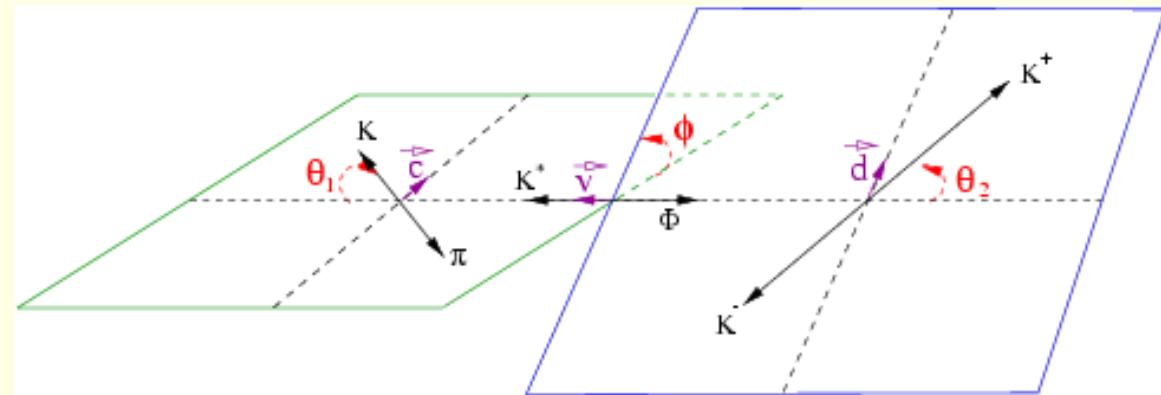
$$C_{\rho\pi} = 0.45^{+0.18}_{-0.19} \text{ (stat)}, \quad S_{\rho\pi} = 0.16 \pm 0.25 \text{ (stat)}.$$

$$\Delta C_{\rho\pi} = 0.38^{+0.19}_{-0.20} \text{ (stat)}, \quad \Delta S_{\rho\pi} = 0.15 \pm 0.26 \text{ (stat)}.$$



$B \rightarrow VV$ [Gritsan, Mir, Breon]

- Three amplitudes - s, p, d waves - possible strong phases
- Direct CP measurements
- Dynamical issues: penguins, factorization, etc.
- In helicity frame:



$$\begin{aligned} \frac{d^2\Gamma}{d\Omega_1 d\Omega_2} \propto & \frac{1}{4} \Gamma_T \sin^2 \theta_1 \sin^2 \theta_2 + \Gamma_L \cos^2 \theta_1 \cos^2 \theta_2 \\ & + \frac{1}{2} \sin^2 \theta_1 \sin^2 \theta_2 (\alpha_1 \cos 2\phi - \beta_1 \sin 2\phi) \\ & + \frac{1}{4} \sin 2\theta_1 \sin 2\theta_2 (\alpha_2 \cos \phi - \beta_2 \sin \phi) \end{aligned}$$

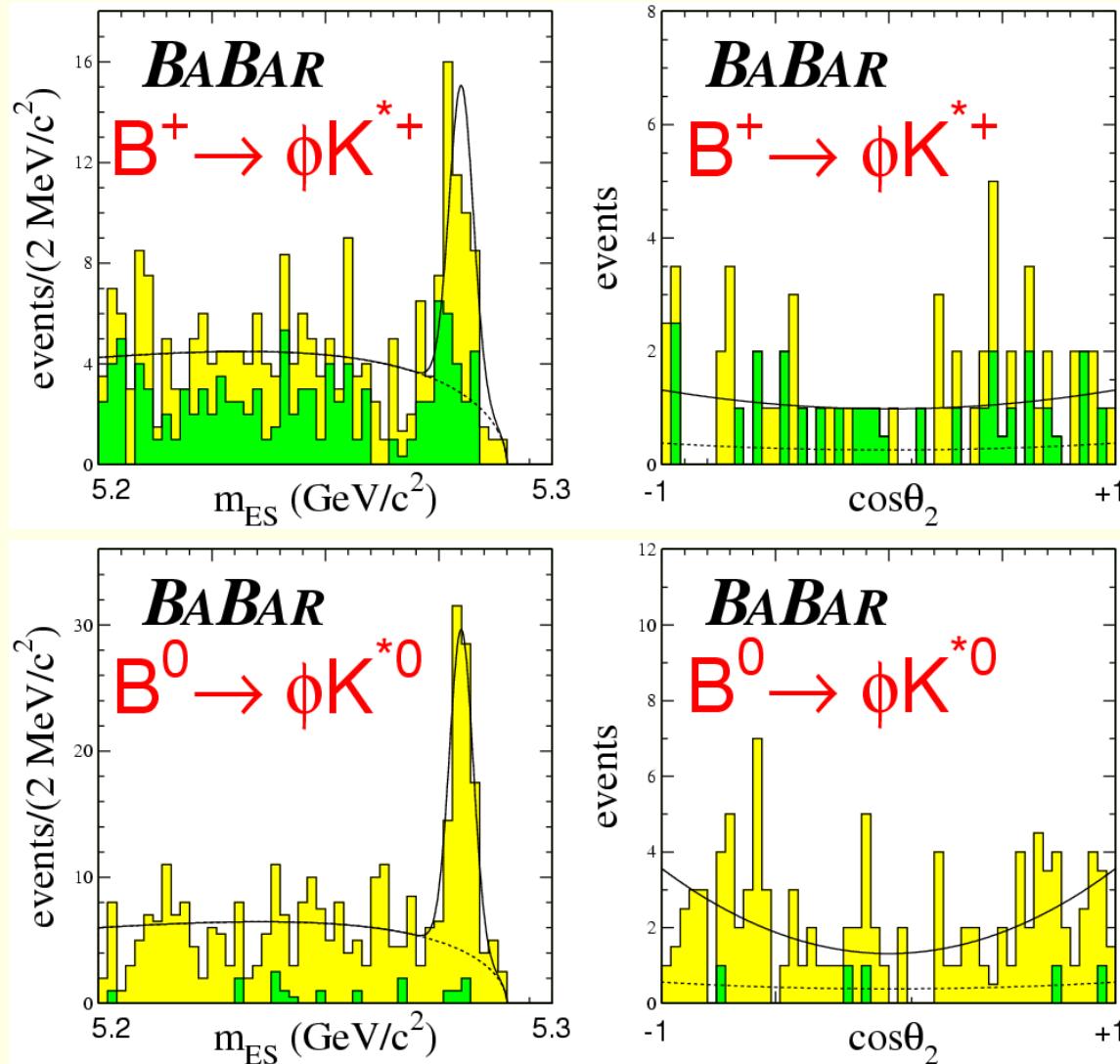


Procedure for $B \rightarrow VV$

- Four-body skim for events consistent with B
- Likelihood fit on mass, energy, shape, two-body invariant masses
- Angular analysis in θ_1, θ_2 (not ϕ)
- Determine longitudinal fraction, f_L
- Include effects of acceptance, backgrounds



$B \rightarrow \phi K^*$ [Gritsan]



- Yellow without π^0
- Green with π^0



Consistency of results in $B \rightarrow \phi K^*$

Mode	$\epsilon_{\text{rec}} (\%)$	$\epsilon_{\text{tot}} (\%)$	N_{fit}	$\mathcal{B} (\times 10^{-6})$	\mathcal{A}_{CP}	f_L
$\phi K^{*0}_{K^+\pi^-}$	29.7	9.7	101^{+12}_{-11}	$11.7 \pm 1.4 \pm 1.1$	$+0.04 \pm 0.12 \pm 0.02$	$0.64 \pm 0.07 \pm 0.03$
$\phi K^{*0}_{K^0\pi^0}$	11.4	0.6	$2.0^{+3.4}_{-1.3}$	$3.5^{+6.1}_{-2.3} \pm 1.1$	-	$1.00^{+0.00}_{-0.66} \pm 0.25$
$\phi K^{*0}_{\text{comb.}}$	-	10.2	-	$11.1^{+1.3}_{-1.2} \pm 1.1$	$+0.04 \pm 0.12 \pm 0.02$	$0.65 \pm 0.07 \pm 0.04$
$\phi K^{*+}_{K^0\pi^+}$	26.0	2.9	$33.3^{+7.2}_{-6.4}$	$12.7^{+2.8}_{-2.5} \pm 1.2$	$-0.02 \pm 0.20 \pm 0.03$	$0.50^{+0.14}_{-0.15} \pm 0.04$
$\phi K^{*+}_{K^+\pi^0}$	14.3	2.3	$22.3^{+7.5}_{-6.5}$	$10.7^{+3.6}_{-3.1} \pm 1.9$	$+0.63^{+0.25}_{-0.31} \pm 0.05$	$0.40^{+0.20}_{-0.19} \pm 0.07$
$\phi K^{*+}_{\text{comb.}}$	-	5.3	-	$12.1^{+2.1}_{-1.9} \pm 1.5$	$+0.16 \pm 0.17 \pm 0.04$	$0.46 \pm 0.12 \pm 0.05$



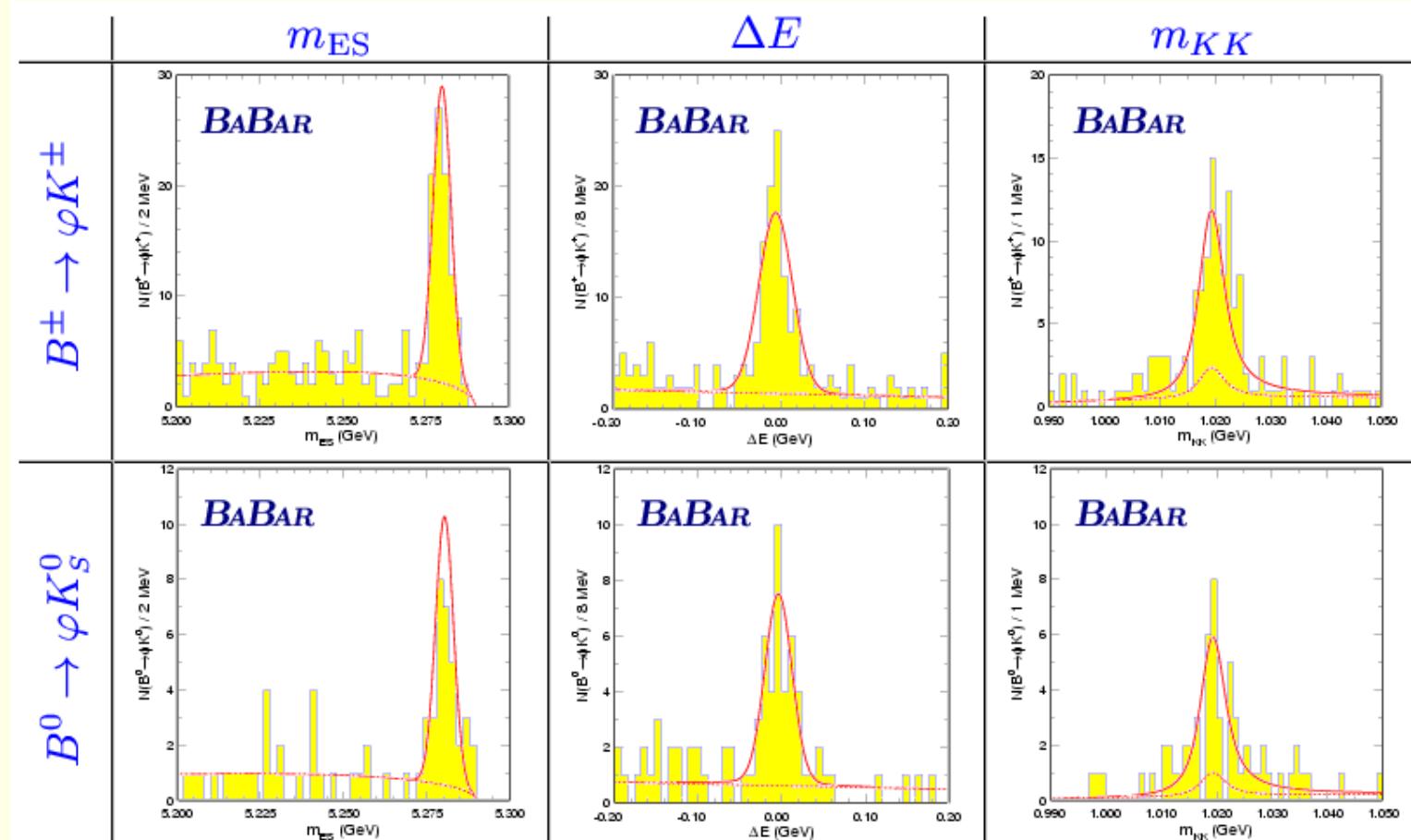
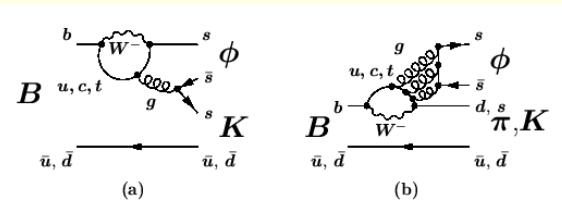
$B \rightarrow \rho K^*$ [Mir, Gritsan] PRELIM.



$B^\pm \rightarrow \rho^0 \rho^\pm$ [Mir, Gritsan] PRELIM.

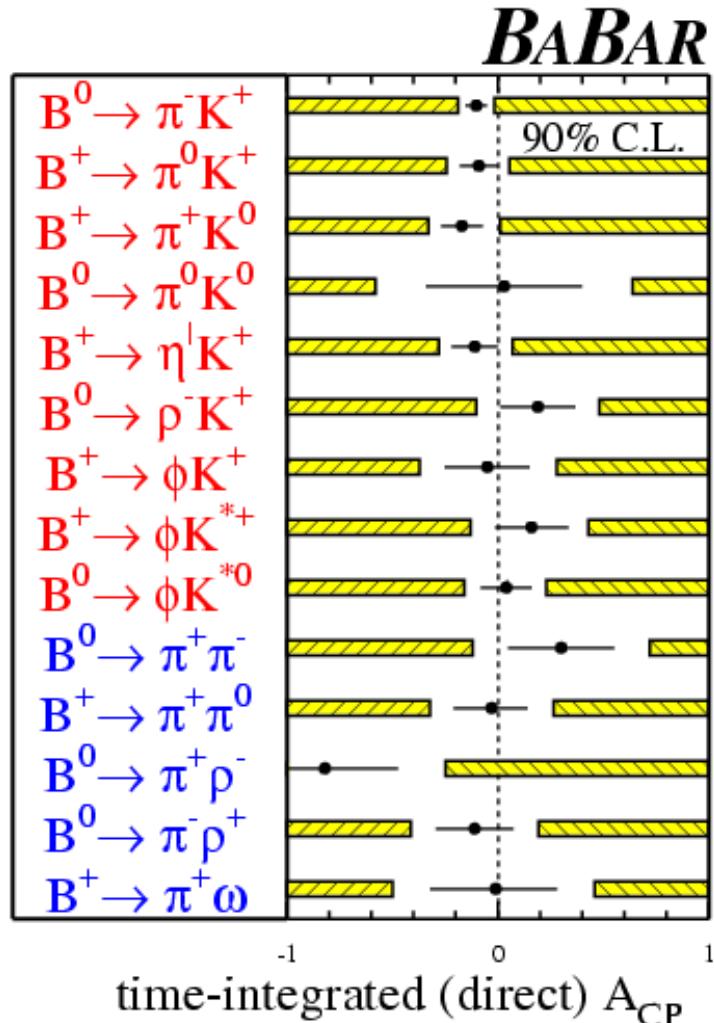


$B \rightarrow \phi K$ [Telnov]





Direct CP Violation [Gritsan]

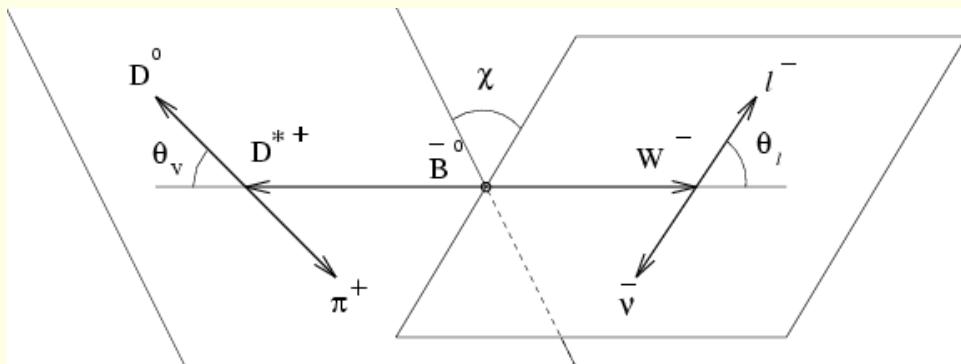


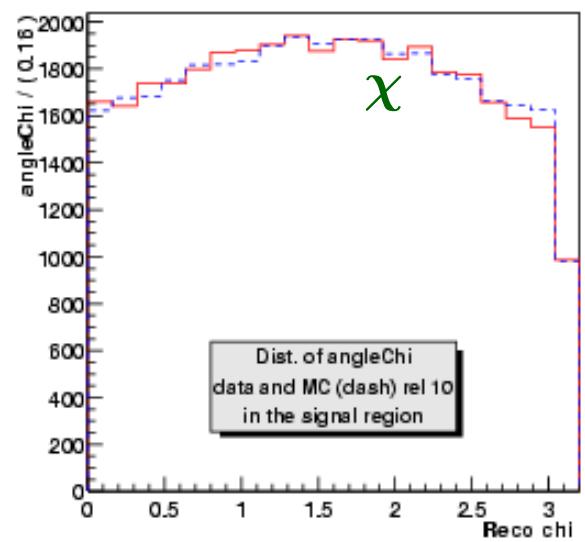
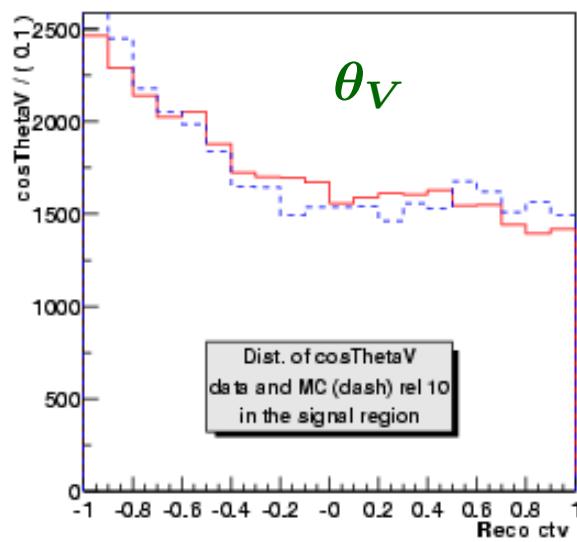
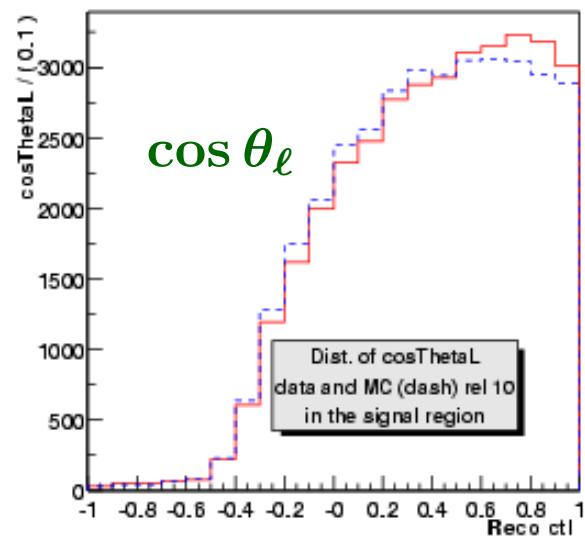
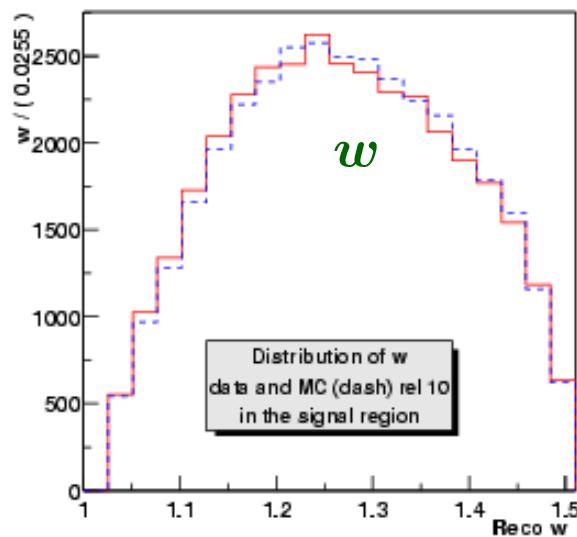
No definitive sign of direct CP violation yet, but interesting suggestions.



$B \rightarrow D^* \ell \nu$ [Gill]

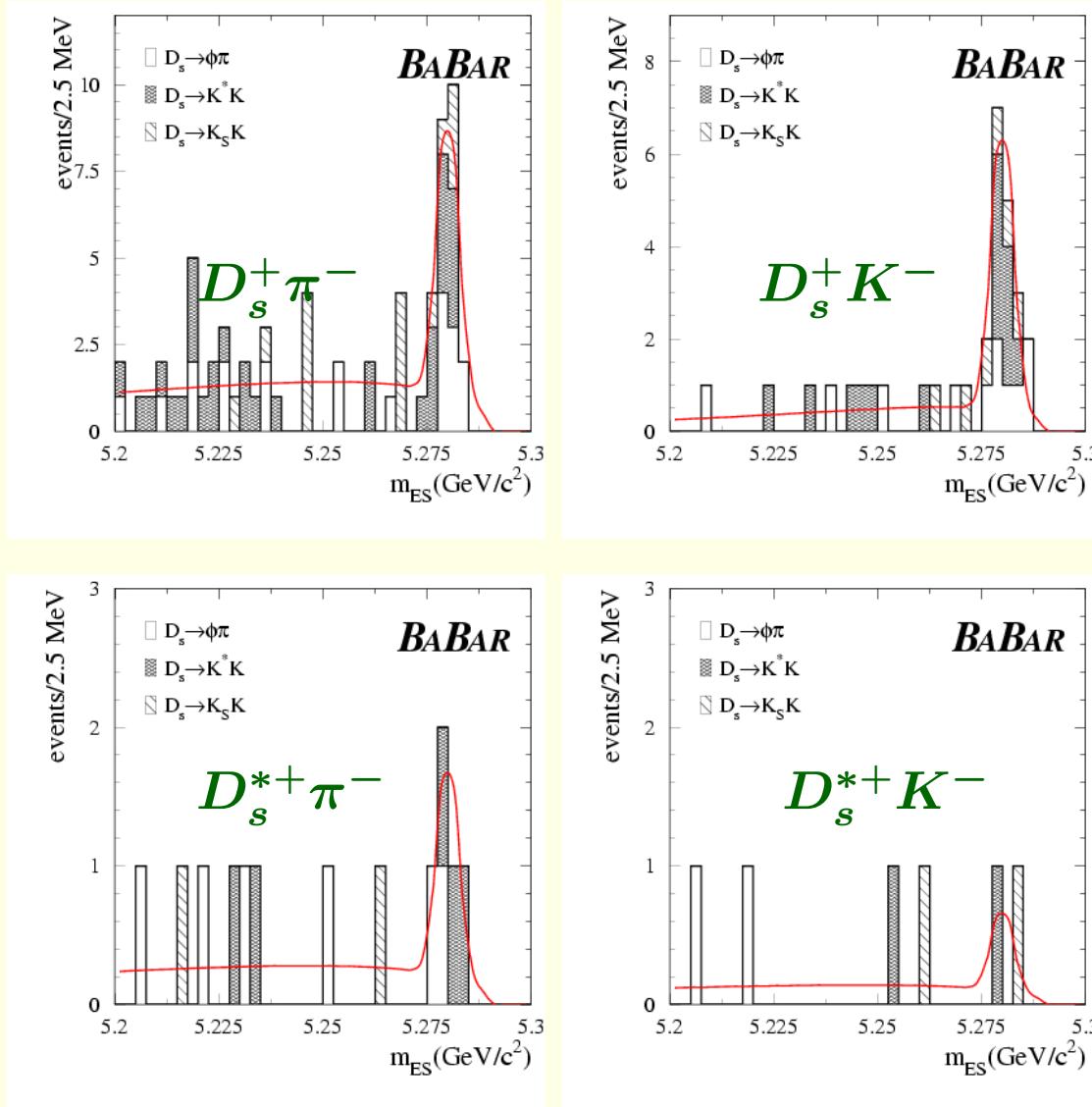
- Form factors test Heavy Quark Effective Theory
- Needed to extract V_{cb}
- Vastly larger dataset than used in CLEO measurement
- Four kinematic variables: $\theta_V, \theta_\ell, \chi, w[q^2]$







$B \rightarrow D_s^* h$ [Kolomensky, Orimoto]



$D_s^+ \pi^-$ is SU(3) variant of doubly Cabibbo suppressed $D^+ \pi^-$. $D_s^+ K^-$ requires W exchange diagram. Connected to measurement of γ in $D^+ \pi^-$.



$B \rightarrow D_s^* h$ [Kolomensky, Orimoto]

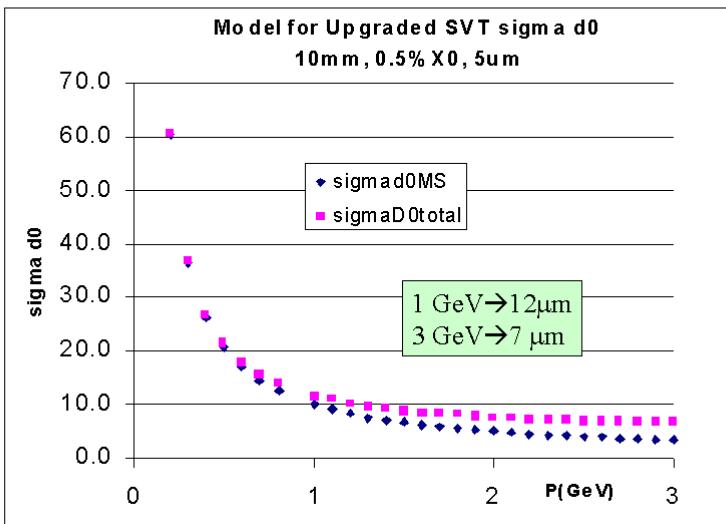


B mode	N_{sb}	N_{gaus}	N_{comb}	N_{cross}	$\epsilon(\%)$	P_{bckg}	$\text{BR}(10^{-5})$	90% C.L. (10^{-5})
$B^0 \rightarrow D_s^+ \pi^-$								-
$D_s \rightarrow \phi \pi^+$	9	8.0 ± 3.0	2.1 ± 0.7	< 0.7	16.9	1.4×10^{-3}	3.1 ± 1.2	-
$D_s \rightarrow \bar{K}^{*0} K^+$	12	9.2 ± 3.4	3.8 ± 1.0	2.9 ± 1.8	9.6	2.3×10^{-2}	3.5 ± 1.9	-
$D_s \rightarrow K_S^0 K^+$	5	4.2 ± 2.2	1.9 ± 0.6	1.2 ± 1.4	12.3	8.3×10^{-2}	2.4 ± 1.8	-
all	26	21.4 ± 5.1	7.8 ± 1.7	3.7 ± 2.4	N/A	9.5×10^{-4}	$3.2 \pm 0.9 \pm 1.0$	-
$B^0 \rightarrow D_s^{*+} \pi^-$								-
$D_s \rightarrow \phi \pi^+$	2	-	0.6 ± 0.3	< 0.14	7.8	-	-	-
$D_s \rightarrow \bar{K}^{*0} K^+$	3	$2.8^{+2.7}_{-1.8}$	0.4 ± 0.3	0.3 ± 0.2	3.3	3.9×10^{-2}	$4.3^{+4.7}_{-3.1}$	< 12
$D_s \rightarrow K_S^0 K^+$	0	-	0.4 ± 0.3	< 0.14	5.1	-	-	-
all	5	$4.4^{+2.7}_{-2.8}$	1.2 ± 0.4	0.3 ± 0.2	N/A	2.3×10^{-2}	$1.9^{+1.2}_{-1.3} \pm 0.5$	< 4.1
$B^0 \rightarrow D_s^- K^+$								-
$D_s \rightarrow \phi \pi^+$	7	5.8 ± 2.6	1.3 ± 0.7	1.1 ± 1.2	13.0	4.5×10^{-2}	2.4 ± 1.3	-
$D_s \rightarrow \bar{K}^{*0} K^+$	8	7.3 ± 2.9	1.7 ± 0.7	< 0.7	7.8	1.9×10^{-3}	5.0 ± 2.0	-
$D_s \rightarrow K_S^0 K^+$	4	3.7 ± 2.0	0.6 ± 0.4	1.3 ± 1.0	9.2	1.7×10^{-2}	2.5 ± 2.1	-
all	19	16.7 ± 4.3	3.5 ± 1.3	2.7 ± 1.9	N/A	5.0×10^{-4}	$3.2 \pm 1.0 \pm 1.0$	-
$B^0 \rightarrow D_s^{*-} K^+$								-
$D_s \rightarrow \phi \pi^+$	0	-	0.8 ± 0.6	< 0.14	5.3	-	-	-
$D_s \rightarrow \bar{K}^{*0} K^+$	1	-	0.4 ± 0.4	< 0.14	2.7	-	-	-
$D_s \rightarrow K_S^0 K^+$	1	-	0.4 ± 0.4	< 0.14	4.3	-	-	-
all	2	-	1.6 ± 0.8	< 0.14	N/A	0.48	-	< 2.5

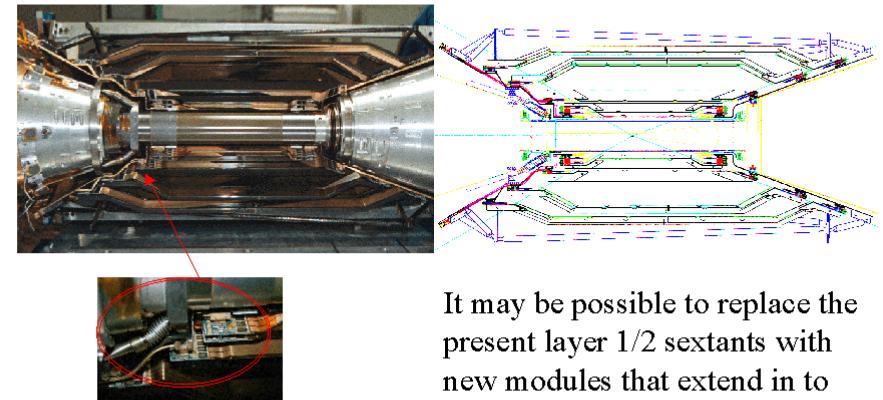


Long-term Task Force: Detector

Model for upgraded SVT



Upgrade Existing SVT or Start Over?



(We have about 800 additional AToM chips; estimate 3 man-yrs to convert AToM to 0.25 um CMOS)

It may be possible to replace the present layer 1/2 sextants with new modules that extend in to a smaller radius, while keeping the rest of the SVT intact.

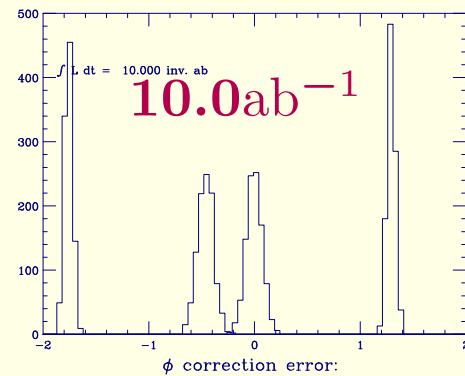
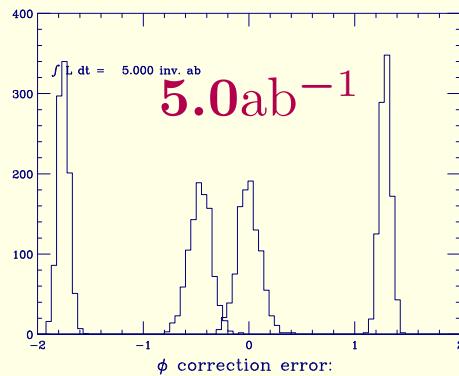
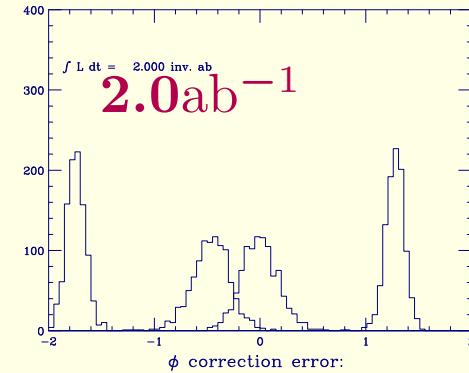
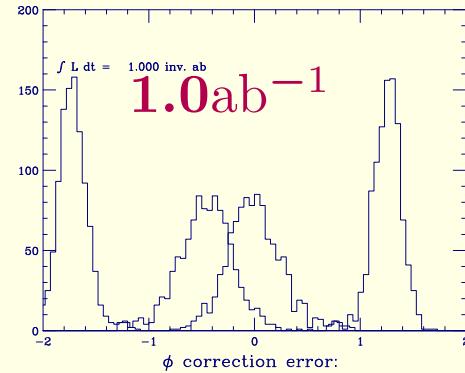
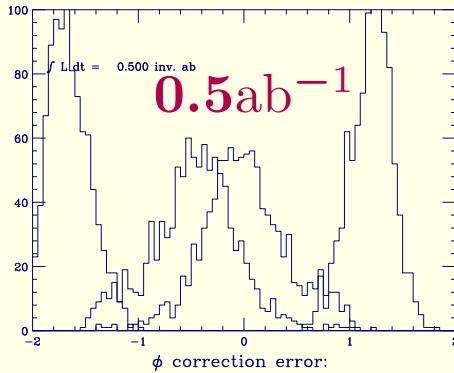


Measuring α with $B \rightarrow \pi\pi$

- Unlike $B \rightarrow J/\psi K_S$, penguins obscure analysis
- Need all isospin variants
- $B \rightarrow \pi^0 \pi^0$ suppressed BR $\leq 2 \times 10^{-6}$
- Measure time-dependent $B^0 \rightarrow \pi^+ \pi^-$, $\bar{B}^0 \rightarrow \pi^+ \pi^-$
- Measure BR for $B^\pm \rightarrow \pi^\pm \pi^0$ (should be identical)
- Measure BR $B^0 \rightarrow \pi^0 \pi^0$, $\bar{B}^0 \rightarrow \pi^0 \pi^0$
- Construct Gronau-London triangle to find $\kappa = 2\alpha - 2\alpha_{eff}$



Toy Monte Carlo: $2\alpha_{eff}$ correction



Discrete ambiguity
and low BR requires
several ab^{-1}



Summary

- BaBar/PEP-II performing well, producing lots of physics
- Challenged every step of the way by Belle
- LBL working to enhance BaBar's performance, especially in SVT, tracking
- LBL providing leadership and innovation in computing - the “mini”
- LBL leading exciting analyses connected to the long-term CP program
- LBL active in planning the future of the experiment